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The Timan-Pechora Basin Province of Northwest Arctic Russia: Domanik – Paleozoic Total Petroleum System

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by

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FOREWORD

This report was prepared as part of the World Energy Project of the U.S. Geological Survey. In the project, the world was divided into eight regions and 937 geologic provinces. The provinces have been ranked according to the discovered oil and gas volumes within each (Klett and others, 1997). Then, 76 "priority" provinces (exclusive of the U.S. and chosen for their high ranking) and 26 "boutique" provinces (exclusive of the U.S. and chosen for their anticipated petroleum richness or special regional economic importance) were selected for appraisal of oil and gas resources. The petroleum geology of these priority and boutique provinces is described in this series of reports. The Timan-Pechora Basin Province ranks 22nd in the world, exclusive of the U.S.

The purpose of this effort is to aid in assessing the quantities of oil, gas, and natural gas liquids that have the potential to be added to reserves within the next 30 years. These volumes either reside in undiscovered fields whose sizes exceed the stated minimum-field-size cutoff value for the assessment unit (variable, but must be at least 1 million barrels of oil equivalent) or occur as reserve growth of fields already discovered.

The *total petroleum system* constitutes the basic geologic unit of the oil and gas assessment. The total petroleum system includes all genetically related petroleum occurring in shows and accumulations (discovered and undiscovered) that has been generated by a pod or by closely related pods of mature source rock and that exists within a limited mappable geologic space, together with the essential mappable geologic elements (source, reservoir, seal, and overburden rocks) that control the fundamental processes of generation, expulsion, migration, entrapment, and preservation of petroleum. The *minimum petroleum system* is that part of a total petroleum system encompassing discovered shows and accumulations, together with the geologic space in which the various essential elements have been proved by these discoveries.

An *assessment unit* is a mappable part of a total petroleum system in which discovered and undiscovered fields constitute a single relatively homogenous population such that the chosen methodology of resource assessment – based on estimation of the number and sizes of undiscovered fields – is applicable. A total petroleum system might equate to a single assessment unit. If necessary, a total petroleum system may be subdivided into two or more assessment units such that each assessment unit is sufficiently homogeneous

[2] Domanik-Paleozoic Total Petroleum System (#100801), northwestern Russia and southern Barents Sea, Timan-Pechora Basin Province (#1008), Former Soviet Union (Region 1)

in terms of geology, exploration considerations, and risk to assess individually. Assessment units are considered *established* if they contain more than 13 fields, *frontier* if they contain 1-13 fields, and *hypothetical* if they contain no fields.

A graphical depiction of the elements of the a total petroleum system is provided in the form of an events chart that shows the time of deposition of essential rock units; the time in which processes (such as trap formation) necessary to the accumulation of hydrocarbons took place; the critical moment in the total petroleum system; and the preservation time, if any.

A numeric code identifies each region, province, total petroleum system, and assessment unit; these codes are uniform throughout the project and will identify the same item in any of the publications. The code is as follows:

	Example
Region, single digit	**3**
Province, three digits to the right of region code	3**162**
Total Petroleum System, two digits to the right of province code	3162**05**
Assessment unit, two digits to the right of petroleum system code	316205**04**

The codes for the regions and provinces are listed in Klett and others, 1997.

Oil and gas reserves quoted in this report are derived from the Petroleum Exploration and Production database (Petroconsultants, 1996) and other reports from Petroconsultants, Inc., unless otherwise noted.

Figure(s) in this report that show boundaries of the total petroleum system(s), assessment units, and pods of active source rocks were compiled using geographic information system (GIS) software. Political boundaries and cartographic representations were taken, with permission, from Environmental Systems Research Institute's ArcWorld 1:3 million digital coverage (1992), have no political significance, and are displayed for general reference only. Oil and gas field centerpoints, shown on this(these) figure(s), are reproduced, with permission, from Petroconsultants, 1996.

ABSTRACT

The Domanik-Paleozoic oil-prone total petroleum system covers most of the Timan-Pechora Basin Province of northwestern Arctic Russia. It contains nearly 20 BBOE ultimate recoverable reserves (66% oil). West of the province is the early Precambrian Eastern European craton margin. The province itself was the site of periodic Paleozoic tectonic events, culminating with the Hercynian Uralian orogeny along its eastern border. The stratigraphic record is dominated by Paleozoic platform and shelf-edge carbonates succeeded by Upper Permian to Triassic molasse siliciclastics that are locally present in depressions. Upper Devonian (Frasnian), deep marine shale and limestone source rocks – with typically 5 wt % total organic carbon – by middle Mesozoic time had generated hydrocarbons that migrated into reservoirs ranging in age from Ordovician to Triassic but most focused in Devonian and Permian rocks. Carboniferous structural inversions of old aulacogen borders, and Hercynian (Permian) to Early Cimmerian (Late Triassic to Early Jurassic) orogenic compression not only impacted depositional patterns, but also created and subsequently modified numerous structural traps within the province.

INTRODUCTION

One major total petroleum system characterizes the Timan-Pechora Basin Province in the Arctic coastal region of northwestern Russia. The source rocks are basinal facies equivalents to shelf-edge reefs ranging in age from Late Devonian (Frasnian) to earliest Carboniferous (Tournaisian). Although similar conditions existed again in Early Permian time, the richest and most volumetrically important source rocks are Frasnian in age and are called "Domanik." Limited mixing is likely from at least two other petroleum systems within or adjacent to this province. A Siluro-Ordovician source rock is postulated to exist in the eastern part of the province (Adzva-Varandey Zone and Kosyu-Rogov Trough, Figure 1), with at least four fields identified as containing some hydrocarbons thus generated. The northern part of the province along the coastal region might also contain mixed hydrocarbons from the generation of and migration from Triassic source rocks offshore in the Barents Sea. Portions of the Timan-Pechora offshore with potential Triassic-sourced hydrocarbons will be discussed further in the South Barents Sea Province evaluation. Not addressed in this review and assessment are unconventional gas reserves are present in coaly siliciclastics of Artinskian and Kungurian age of the Timan-Pechora foredeep regions (Ben Law, U.S. Geological Survey, personal communication).

References listed in this report include a limited selection of those most recent and most pertinent to this document. Not all are specifically cited in the text. The stratigraphic equivalents chart is composited from many references to approximately equate the range of stratigraphic nomenclature in use. It is not intended to be precise with respect to absolute geologic age.

PROVINCE GEOLOGY

Province Boundary and Geographic Setting

The Timan-Pechora Basin Province overlies the Arctic Circle, extending across 61°-72° north latitude and 44°-66° east longitude (Figure 1). To the east, outside the province boundary, is a sinuous fold belt including the Ural Mountains, the Pay-Khoy Ridge, Vaygach Island and the Novaya Zemlya archipelago. To the west is the NW-SE trending Timan-Kanin Ridge, which intersects the Ural Mountains at the southern end of the province. The northern offshore province boundary is the South Barents transitional fault zone, separating the excluded South Barents basin of the Barents Sea from the included Pechora block within the Pechora Sea (Figure 2a). Onshore geologic features are known to extend offshore. Onshore area (70%) of this province is 315,100 sq km (121,629 sq mi) and includes the drainage basins of the Pechora, Usa, and Izhma Rivers. Offshore (30%) are 131,700 sq km (50,836 sq mi), of which approximately 5,400 sq km (2,084 sq mi) comprise islands.

Political Entities

The Timan-Pechora Basin Province is entirely within the Russian Federation of the former Soviet Union, but Russia is divided into political units with different legislative and jurisdictional responsibilities. Most of Timan-Pechora is within the Komi republic – which includes most of the known current production – but large fields yet to be developed are within the Nenets Autonomous Okrug of Arkhangel'sk Oblast (Sagers, 1994).

Geologic Setting

The Timan-Pechora Basin Province is on the Pechora crustal plate (late Proterozoic basement) northeast from the margin of the Precambrian (Archean to early Proterozoic) Eastern European craton. The area periodically was the site of Proterozoic rifting and continental suturing (Bashilov and Kuprin, 1995; Bogatsky and others, 1996), approximately parallel with the Timan Ridge that borders the province to the southwest (Figures 1, 2b, 2c). During periods of collision, a subduction zone and volcanic arc system existed offshore to the northeast.

The Timan Ridge includes accreted and uplifted, slightly metamorphosed basement. It has been a west-verging thrust complex (Sobornov and Rostovshchikov, 1996) and perhaps even a left-lateral wrench zone (Ulmishek, 1988; Mezhvilk, 1995). Faults separating the Timan Ridge from the easterly adjacent Izhma-Pechora Depression have 0.5-0.8 km offsets (Bogatsky and others, 1996).

Baikalian (Riphean-Vendian) basement of the Timan Ridge uplift and the Izhma-Pechora Depression is relatively homogeneous and rigid. Basement in the Pechora-Kolva Aulacogen and regions eastward (Figure 1) changes to that of active margin and transitional crust (Bogatsky and others, 1996), with greater compositional heterogeneity that resulted in repeated fault activation and structural inversion through time. Thus, the Pechora-Kolva Aulacogen and the Adzva-Varandey Zone (also a possible aulacogen) contain shallow structures discordant with those at basement level (Figures 1 and 2b). Old aulacogen borders are marked with shallow anticlines known as the Pechora-Kozhva, Shapkino-Yuryakha, Kolva, Sorokin, and Chernov Swells. The Lay and Bolshezemelsk basement arches are masked by overlying shallower basins (Denisov and Khoreyver Depressions, respectively). Basement crops out in the Timan Ridge and Ural Mountains, but attains 12-14 km depths in eastern foredeep basins bordering the western side of the Ural and Pay-Khoy / Novaya Zemlya fold belts.

After latest Proterozoic plate collision (post-Riphean, pre-Vendian "Baikalian Orogeny"), the Timan-Pechora region was a passive continental margin for much of the following Paleozoic era, with episodes of Ordovician and Devonian rifting (Driscole and Golden, 1995; Dedeyev and others, 1996; Sobornov and Rostovshchikov, 1996; Ismail-Zadeh and others, 1997) (Figure 3). Paleozoic cratonic landmasses were to the west-southwest, with the Uralian Ocean to the east-northeast. Earliest Paleozoic basin fill gradually changed from siliciclastic- to carbonate-dominated. Upper Ordovician evaporites were deposited in the eastern parts of the province (Tarbayev and others, 1991; Stepanova, 1994).

Significant Middle Devonian aulacogen rejuvenation (Pechora-Kolva, possibly Varandey-Adzva, Figure 1) was concurrent with basaltic volcanism and the appearance of siliciclastics locally from the west. Eastward prograding, major shelf-edge reef systems bordered elongate, restricted intrashelf basins where rich organic matter was preserved ("Domanik" facies). During the following Carboniferous Period, structural inversions again were associated with localized influxes of siliciclastics and precipitation of evaporites (Lower Carboniferous, Figure 3), but Tournaisian reefs were less extensive than Upper Devonian varieties.

By Permian time, the Hercynian Orogeny brought compression from the east, thrusting slope and deep marine rocks over their shelf counterparts and creating the proto-Ural Mountains and their molasse-filled foredeep basins. Timan-Pechora's major provenance eventually changed to an easterly sourced, siliciclastic-dominated style. Structural inversions, combined with sea-level fluctuations, resulted in complex facies distributions and periods of erosion. Major Early Permian shelf-edge reefs proliferated, and a subsequently continuous subsidence began in the Barents Sea Basin to the north. Timan-Pechora Triassic and later sedimentation became largely continental in the southern regions.

The Pay-Khoy / Novaya Zemlya fold belt and its foredeep basins were created in Late Triassic to Early Jurassic time (Early Cimmerian Orogeny), post-dating formation of the Ural foldbelt. The compressional eastern boundary of the Timan-Pechora Basin Province was most recently uplifted again in late Tertiary time, but that Neogene deformation was largely restricted to the eastern mountain margin bordering western Siberia (Sobornov and Rostovshchikov, 1996). Overall, the Timan-Pechora Basin is filled with 55-60% carbonates, 35-40% siliciclastics and about 5% evaporites (Dedeev and others, 1994).

Exploration History

Over time, the focus of Timan-Pechora oil and gas exploration migrated from the southwestern part of the province – where seeps abound and permafrost is rare – to the northeastern region where the land is swampier and lower in elevation and has year-round permafrost. The entire province is characterized with extreme cold temperatures, and not all fields produce regularly. New joint ventures have been established with Western industry.

The presence of oil near Ukhta in the southwestern part of the Timan-Pechora Basin Province was known as early as 1595, and between 1869 and 1917, thirty non-commercial shallow wells were drilled in the area (Meyerhoff, 1980). Four classifications of wells (new-field wildcats, exploratory, outpost and development) account for 98% of the 3,878 additional wells drilled in the province through 1995 (Petroconsultants, 1996). The remaining 2% include service wells, water wells and "stratigraphic" tests. The first commercial oil field (Chib'yu) was discovered in 1930 and the first commercial gas field (Sed'yol) in 1935.

Unfortunately, spud or completion dates are not available for 62% of the well population, but Figure 4 illustrates from the known population the significant amount of drilling that began in the mid 1940s (most early wells classified as outposts) and has continued to present. In recent years, the numbers of wells categorized as new field wildcats and exploratory wells have increased relative to those classified as outposts and development wells.

PETROLEUM OCCURRENCE

Geographic and Stratigraphic Location

Oil seeps and tar sands are common in the Timan-Pechora Basin, even within Precambrian (Riphean) rocks of the Timan Ridge (Sobornov and Yakovlev, 1996). Petroconsultants (1996) lists 257 fields within the province (Table 1), but 31 fields have no production or reserve data published. For the Timan-Pechora Basin Province, known ultimate recoverable reserves of nearly 20 BBOE are distributed as 66% oil, 30% gas and 4% condensate. Five fields are significantly distant from the mainland (Figures 1 and 5). The two northernmost fields on Kolguyev Island are likely associated with a different petroleum system in the offshore South Barents Sea Basin (Table 1).

Foredeep basins on the east side of the Timan-Pechora Basin Province are gas dominated, as are both the southwesternmost area along the Timan Ridge and the northern coastal region of the Shapkino-Yuryakha and Lay Swells (northern part of Pechora-Kolva Aulacogen, Figure 1). The southern foredeep (Upper Pechora Trough) contains the province's largest field – Vuktyl, with nearly 50% of the province's known recoverable gas – but northeastern foredeep basins (Kosyu-Rogov and Korotaikha) are sparsely explored. The northern Izhma-Pechora Depression contains few fields despite having approximately 100 well penetrations. Offshore Timan-Pechora has both oil and gas fields, and fewer than a dozen offshore exploratory wells have been drilled away from islands.

Hydrocarbons are trapped in Ordovician through Triassic reservoir rocks at 200 to 4500 meter depths (Kiryukhina, 1995). Scenarios for multi-stage hydrocarbon migrations and remigrations are possible, particularly in the Ural foredeeps, because of regionally variable burial history and the province's repeated tectonism (Bogatsky and Pankratov, 1993). Most oil is reservoired in tectonically stable areas with stratigraphic traps (Bogatsky and Pankratov, 1993). Conversely, most gas (alone or with oil) is in active tectonic areas where more recent gas charging could have occurred. Late Cenozoic Uralian uplift probably resulted in cooling and decompression of formation fluids, allowing gas to come out of solution and accumulate in traps (Sobornov and Rostovshchikov, 1996).

Geochemistry of Hydrocarbons

Timan-Pechora hydrocarbons range from high gravity, low sulfur and low resin oils with paraffin bases to low gravity, high sulfur and high viscosity oils of dominantly aromatic-napthenic compositions (Kiryukhina, 1995). Sulfur content is related to the presence of evaporites, and Kosyu-Rogov (foredeep basin) gases contain H_2S. Commonly, oils in stratigraphically older reservoirs have lower density, fewer asphaltenes and more residual components than those in stratigraphically younger reservoirs (Meyerhoff, 1980). Biodegradation occurs in shallow accumulations. Province-wide, oil gravity ranges from 11°-62° API and condensate gravity from 45°-79°API (Petroconsultants, 1996). From the same reservoir and test data, mean and median API gravity is 35°, and GOR has a mean of 393 cfg/bo and a median of 289 cfg/bo (range 7 to 1500 cfg/bo). The higher end of the GOR range is probably the more appropriate characterization for this province.

Oil attributed to Upper Devonian ("Domanik") source rock has the following characteristics (Abrams and others, 1999):

- Pristane/phytane >1 and <2
- Smooth distribution of n-alkanes, with a maximum at C_{11} - C_{15}
- Saturates/aromatics < or = 1
- Abundant C_{28+}
- $\delta^{13}C$ saturates and aromatics ≅ -29
- Sulfur content = 1 - 4.5 wt %
- Normal to low tricyclics with $C_{24} > C_{26}$
- C_{29} hopanes < or = C_{30} hopanes
- Generated at conditions less than peak oil for typical type II kerogens

Hydrocarbons from other source rocks have geochemical distinctions. Ordovician- to Silurian-sourced oils have pristane/phytane = 1; a sawtooth alkane distribution with a predominance up to C_{19}, odd preference, and a maximum near C_{15}; $\delta^{13}C$ for saturates and aromatics = -31; hopanes $C_{29} < C_{30}$; and high tricyclics (Abrams and others, 1999). Ordovician to Silurian oils were generated near peak rates for a type II kerogen.

Offshore oils possibly from marine to marginal-marine Triassic source rocks have variable geochemical and isotopic signatures (Zakharov and Kulibakina, 1997). Rare, shallow gas occurrences in Triassic reservoirs of the Pechora-Kolva Aulacogen are biogenic in origin (Pairazian, 1993).

Migration Paths and Petroleum System Size

The Timan-Pechora Basin Province contains 20 BBOE known ultimate recoverable reserves, 29% produced through 1995 (Petroconsultants, 1996). Sixty-six percent is oil (13.157 BB, 25% produced), 30% is gas (36.535 TCF, 34% produced), and 4% is condensate (716 MMB, 51% produced). Approximately 5% of the reserves are in 6 fields that were mixed with or perhaps entirely sourced from petroleum systems (Triassic, Siluro-Ordovician) other than the Devonian Domanik (Table 1).

Migration paths are not exceptionally long because the primary Devonian source rock is present and at oil- or gas-stage maturity over most of the onshore area. Direct charging occurs laterally from the source rock into coeval reservoir rock, as well as by vertical migration through strata and along faults. Remigration occurred with repeated tectonic activity (Dedeev and others, 1994). Potential southward updip migration of Triassic-sourced hydrocarbons from the South Barents Basin required long distances of travel, likely assisted through NW and NE trending fault systems (Oknova, 1993). Paleozoic carbonates and sandstones are the major Timan-Pechora reservoirs (Table 2).

SOURCE ROCK

Geographic and Stratigraphic Location

Major Source Rock

The primary source rocks ("Domanik," Figures 3 and 6) of the Timan-Pechora Basin Province are organic-rich, basinal facies equivalents of shelf-edge reefs. Late Devonian (Frasnian) source rocks constitute the largest area, although similar depositional conditions existed in more areally restricted depocenters through earliest Carboniferous (Tournaisian) time (Ulmishek, 1988; Alsgaard, 1992) and again in different basin centers during Early Permian time. The Frasnian depositional basin was extensive in a N-S direction from the region of the Caspian Sea in west Kazakhstan and southwest Russia, northward an unknown distance offshore into the Pechora Sea (southern Barents Sea). Sapropelic to humic organic matter has been documented for non-Domanik Devonian through Triassic rocks on Kolguyev Island (Bro and others, 1990). Old aulocogen borders likely had some influence on where the abrupt facies changes occurred from shelf carbonates to basinal-equivalent facies. Paleozoic deep basinal facies are absent in the northern Izhma-Pechora Depression and questionable in the easternmost foredeep area of the province near the junction of the Pay-Khoy Ridge with the Ural Mountain trend (Ulmishek, 1988) (Figure 1). Basinal facies are absent in large portions of the Khoreyver Depression.

Other Source Rocks

Possible Siluro-Ordovician source rocks are presumed to exist in the eastern part of the province (Adzva-Varandey Zone, Kosyu-Rogov foredeep basin), associated with known local evaporites. Triassic and Jurassic source rocks are also present north of this province in the Barents Sea basins, and Triassic-sourced oil and gas has charged some northern Timan-Pechora reservoirs (Zakharov and Kulibakina, 1997; Kuranova and others, 199?). Jurassic source rocks are thin (few tens of meters, Oknova, 1993) and thermally immature at the closest proximity to the offshore portion of the Timan-Pechora province.

Thickness, Lithology and Depositional Environment

Domanik source rocks are basinal facies equivalents of shelf-edge reefs and are composed of thin-bedded, dark-colored siliceous shales, limestones and marls with calcareous, siliceous, phosphatic and pyritic concretions. They were deposited in 100-400 meter water depths under reducing conditions with restricted circulation and low sedimentation rates during a eustatic highstand (Alsgaard, 1992; Abrams and others, 1999). Algal content is high. Thicknesses range from a few tens to 500 meters (Shimansky and others, 1995), and abrupt facies and thickness variations document the presence of active graben systems during deposition. Western provenance and an eastward monoclinal tilt to the basin caused the western shelf edge to prograde eastward through time (Ulmishek, 1988). In contrast, reefs on the eastern (West Ural) basin margin were aggradational in character. Few pinnacle or patch reefs developed in the depositional system.

Geochemistry of Source Rock

Major Source Rock

Domanik (middle Frasnian) source rocks contain sapropelic, type I and type II organic matter with TOC (total organic carbon) content ranging from 1-30 wt %, but more typically averaging around 5 wt % (Alsgaard, 1992; Pairazian, 1993; Bazhenova, 1995; Sobornov and Rostovshchikov, 1996; Abrams and others, 1999). Hydrogen indices (HI) range from 500-700 mg/gC, documenting the oil-prone nature of the organic matter (Abrams and others, 1999). Domanik source rocks are present, with adequate thicknesses and maturity level, almost everywhere production has been established. Geochemical data (gas chromatography – mass spectrometry, Rock Eval pyrolysis, biomarker analysis, total organic carbon content, thermal maturity indicators, gas chromatography and kerogen type) derived from the source rock and its extracts confirm Domanik source rocks as providing most of the Timan-Pechora hydrocarbons (Smale and others, 1994; Schamel and others, 1994; Abrams and others, 1999).

Other Source Rocks

Although immature to charge Timan-Pechora reservoirs, extensive Late Jurassic to Early Cretaceous (mostly Kimmeridgian) type II shales in the Barents Sea have TOC content of 10-17 wt % (Oknova, 1993). Permian core samples have TOC content documented as high as 2 wt %, with kerogen type ranging from sapropelic to humic in a west-to-east direction (Timoshenko and others, 1998). Siluro-Ordovician source rocks have not been geochemically identified, but analyzed core samples had TOC content of 0.5-1.5 wt % and HI as high as 302-457 mg/gC (Abrams and others, 1999), with type I and type II kerogens (Sobornov and Rostovshchikov, 1996).

OVERBURDEN ROCK

Geographic and Stratigraphic Location

Timan-Pechora overburden of the primary Domanik source rock generally thickens in an easterly direction, corresponding to the paleolocations of the Uralian seaway and the Hercynian and Early Cimmerian foredeep basins. But that trend is irregular around old aulacogen borders because marginal grabens experienced periodic structural inversions since late Early Carboniferous time and thus less overall burial than adjacent regions. Domanik overburden includes Late Devonian through Cretaceous strata (Figure 6). The South Barents Basin – potentially impacting the northernmost part of the offshore Timan-Pechora Basin Province – has accumulated overburden continuously since Early Permian subsidence began.

Thickness, Lithology and Depositional Environment

Late Devonian through Early Permian time was dominated by carbonate deposition on the Uralian marine shelf. Development of Hercynian foredeep basins changed not only the provenance direction (from westerly sourced to easterly sourced), but also the dominant lithology of the basin (from platform carbonates to molasse siliciclastics). Mesozoic sedimentation varied between continental and marine, and the Jurassic and Cretaceous rock records contain evidence for marine transgressions from the north.

Total Domanik overburden in the province ranges from approximately 2-8 km (Ulmishek, 1982). Pairazian (1993) published a comparative family of burial history curves and maturation profiles across the Timan-Pechora basin (Figures 7a, 7b, 7c, 7d, 7e, 7f). Exact locations for each profile were not provided, and it should be noted that other authors report significantly later and contradictory times of generation and migration. The Figure 7 series should be used primarily to compare regional differences in burial history and not absolute times of hydrocarbon generation. Deepest burial histories are in foredeep areas (Figure 7f) and portions of the Pechora-Kolva Aulacogen (Figure 7c), and shallowest burial histories are in the western Izhma-Pechora Depression (old craton margin) (Figures 7a, 7b). The 100-km-wide Pechora-Kolva Aulacogen has post-Domanik isopachs that thicken westward both because of western provenance and a listric, down-to-the-east origin for its western bounding fault (Sobornov and Yakovlev, 1996).

A recently published burial history curve (Martirosyan and others, 1998, Figure 8) for the Sorokin Swell coastal area illustrates the Permo-Triassic time frame more typically proposed for the maturation of Domanik source rocks.

Pre-Hercynian strata overlying Domanik source rocks range from 0.8-4 km in thickness, with syn- and post-Hercynian rocks through Triassic age ranging from approximately 0.5-4 km in thickness (Ulmishek, 1982). Whereas pre-Triassic rocks generally thicker only from west to east, Triassic rocks additionally thicken to the north offshore. Jurassic and Cretaceous strata range from thicknesses of about 0.2-1 km on the Timan-Pechora platform to 2.5-3.5 km offshore into the South Barents Depression (Ulmishek, 1982; Johansen and others, 1993).

Geothermal Gradient

Present thermal gradients in the Timan-Pechora Basin Province are moderate, from 19°-35° C/km (1.0°-1.9°F/100 ft), but heat flow was probably higher in Early to Middle Mesozoic time, as suggested by the presence of Triassic extrusive rocks (Ulmishek, 1982; Pairazian, 1993; Nevskaya, 1995; Abrams and others, 1999). Higher thermal gradients characterize the area along the East Timan Swell, the Pechora-Kolva rift area, portions of the Kosyu-Rogov and Korotaikha foredeep basins and the northernmost offshore portion of the Timan-Pechora Province (Nevskaya, 1995).

Thermal Maturity of Source Rock

The primary Domanik source rock is thermally mature in most of the Timan-Pechora Basin Province (Figures 5 and 6), but there is considerable disagreement as to exactly when thermal maturity was first reached in different parts of the province. In areas with deepest burial histories (e.g., foredeeps or west side of Pechora-Kolva Aulacogen) or where the thermal gradient has been higher, oil generation began earliest.

According to Ulmishek (1982) and Martirosyan and others (1998), earliest generation was late Early Permian (Figure 8), but Shimansky and others (1995) suggest Late Carboniferous and Pairazian (1993) promotes Early Carboniferous (Figures 7a, 7b, 7c, 7d, 7e, and 7f). Gas generation began as early as Late Permian to Early Triassic time (Ulmishek, 1982). In contrast, on more stable platform areas, oil generation might not have begun until the late Triassic to early Jurassic periods, with the process halting during later uplift and never reaching the stage of gas generation (Ulmishek, 1982; Dedeev and others, 1994; Schamel and others, 1994; Abrams and others, 1999). Most authors believe that Domanik hydrocarbon generation post-dates or overlaps the timing of trap formation resulting from Carboniferous-Triassic structural inversions and orogenies, but Pairazian (1993) proposes significant Early Carboniferous Domanik generation – at least partly pre-dating major trap formation. Oil generation had probably peaked by middle Jurassic time (Schamel and others, 1994; Abrams and others, 1999).

Lower Permian potential source rocks have only reached peak-generation stage to oil in the Uralian foredeeps (Ulmishek, 1982) and perhaps in parts of the Pechora-Kolva Aulacogen. Potential Silurian source rocks generated oil as early as Late Devonian to Early Carboniferous time, post-dating or coinciding with only the earliest inversion and trap formation (Schamel and others, 1994). By the time of the Hercynian and Early Cimmerian orogenies, deepest Siluro-Ordovician source rock would have been generating wet gas.

TRAP STYLE OF OIL AND GAS FIELDS

Trap Style, Characteristics, and Development

Nearly 90% of Timan-Pechora known ultimately recoverable reserves are reported to be in structural traps (Petroconsultants, 1996) – including 95.6% of reserves in sandstones and 84.6% of reserves in carbonates (Table 2) – but stratigraphic targets are underexplored. The pre- and post-Middle Devonian unconformities provide significant potential trapping mechanisms province-wide.

Hercynian (latest Paleozoic) Ural foredeep basins and Early Cimmerian (early to middle Mesozoic) Pay-Khoy counterparts contain thrusted, blind-thrusted and duplexed anticlines. Total shortening in the thrusted regions ranges from 60 to hundreds of km, and prospective subthrust anticlines can extend 15 km or more beyond the westernmost surface expressions of the thrust belt (Sobornov and Bushuyev, 1992). Mostly, only hanging-wall anticlines with surface expressions have been tested with wells, and they produce hydrocarbons at depths ranging from 1.5 - 4.5 km (Sobornov and Rostovshchikov, 1996), including the largest Timan-Pechora producing gas field, Vuk'yl. Folded and faulted, pre-Artinskian (middle Early Permian) shelf carbonates – potential reservoirs at 1-5 km depths – underlie their westward-thrusted, slope-facies, age equivalents. Detachments occur in Artinskian and Kungurian shales and evaporites. Those shales are thermally mature locally and provide both source rock and seal potential. Additional detachments in Upper Devonian to Lower Carboniferous shales and in Upper Ordovician evaporites create more complex structural deformation in the Kosyu-Rogov and Korotaikha foredeeps to the northeast.

Structural inversion on the margins of the Pechora-Kolva and Varandey-Adzva Aulacogens began by middle Carboniferous time and continued intermittently throughout the Hercynian and Early Cimmerian orogenies. Such activity ultimately created anticlines with as much as 1000 meters of relief (Schamel and others, 1992; Schamel and others, 1994). Numerous, large producing fields – including the two largest oil fields in the province, Usa and Vozey – produce from these anticlinal trends. The Pechora-Kolva Aulacogen is also prospective where it projects southeastward under the Uralian foredeep.

Shallow structural closures in the more stable Izhma-Pechora Depression have 20-100 meter amplitudes, and one of the largest closures there is 4x20 km in area (Ulmishek, 1982). Paleozoic and Early Mesozoic stratigraphic and combination traps against old normal faults, paleo-horsts, and several basement arches (e.g., Bolshezemelsky Arch, Lay Swell) are expected throughout the province (Dedeev and others, 1994; Aleksin and others, 1995; Sobornov and Yakovlev, 1996).

A summary of the distribution of oil and gas by reservoir horizon and by lithology is in Table 2. "Reservoir age" is the top of the reservoir interval reported by Petroconsultants (1966). Forty-two percent of the known recoverable reserves cannot be allocated easily to specific strata, based on available data, but pre-Hercynian upper Paleozoic reservoirs (Middle to Upper Devonian and Lower Permian) apparently account for the bulk of producible hydrocarbons. Ulmishek (personal communication, 1999) believes that productive capability from Middle Devonian siliciclastics is significantly under-represented in the table and perhaps captured within the "Upper Devonian" category. From the Petroconsultants allocatable data, carbonates would outproduce sandstones 54% to 46% in known recoverable volumes.

Stratigraphic-pinchout and normal-fault traps were created as early as Ordovician time during the opening of the Uralian Ocean and then again with aulacogen formation or rejuvenation during the Devonian period (Figure 6). Some 150 m.y. of subsequent periodic structural inversion continuously created new structural traps, destroyed others, and impacted sedimentation patterns, culminating in the Hercynian and Early Cimmerian orogenies (Figure 3). The regionally varying times of hydrocarbon generation (Carboniferous to Jurassic) overlapped the Late Paleozoic to Early Mesozoic tectonic cycle of trap formation and destruction. Dedeev and others (1994) believe that just 2-3% of all generated hydrocarbons remain trapped in the Timan-Pechora Basin.

<u>Discovery History</u>

The first commercial Timan-Pechora oil discovery, Chib'yu field, with basal Frasnian (upper Devonian) Pashiy sandstone reservoirs, was in 1930. Two years later, heavy oil (19° API) was discovered at nearby shallow Yarega field in Middle Devonian sandstones, which have been exploited by shaft mining and steam injection since 1939. Yarega currently is the 6th largest field in the Timan-Pechora Basin Province with respect to ultimate recoverable reserves (Petroconsultants, 1996). In 1934, 240 km farther northeast near the town of Pechora, Yugid field was discovered with oil in Lower Carboniferous sandstones.

First commercial gas, also in Devonian sandstones, was discovered in Sed'yol field, near Ukhta, in 1935. The largest province gas field, Vuktyl, was discovered in 1964 in Paleozoic carbonates of the southern Ural foredeep and has nearly 18 TCF in original reserves (Meyerhoff, 1980). Seven fields exceed 0.5 BBOE in ultimately recoverable reserves (Petroconsultants, 1996), and they were discovered in the following sequence, listed by decreasing size: #1 Vuktyl, 1964; #2 Usa, 1963; #3 Vozey, 1971; #4 Kharyaga, 1977; #5 Layavozh, 1969; #6 Yarega, 1932; and #7 Kumzhinskoye, 1975.

RESERVOIR ROCK

Identification and Description

Timan-Pechora reservoirs range in age from Upper Ordovician to Triassic (Table 2, Figure 6) and cover most of the province except for the northern Izhma-Pechora Depression to the west. The largest volume of reserves is in Middle/Upper Devonian siliciclastics and Lower Permian carbonates. An early Paleozoic progression from limited continental to extensive marine depositional environments characterized the province, with a return to dominantly continental conditions by Late Permian and Triassic time. Offshore extensions of nearly all reservoir trends are underexplored.

Basal Ordovician siliciclastics are underexplored for deep structural and stratigraphic traps in what are now the Upper Pechora and Kosyu-Rogov foredeep basins and, if present, within the Khoreyver Depression. Ordovician through Lower Devonian reservoirs average 10-30 meters in net thickness and are mostly carbonates in structural and stratigraphic traps, focused in the southern Khoreyver Depression, the Adzva-Varandey Zone, and the Kosyu-Rogov Trough (Figures 1 and 2b).

Middle Devonian reservoirs are all unconformity-encased sandstones of western provenance, with an isopach thick extending from the Upper Pechora Trough northward through the Pechora-Kolva Aulacogen (Ulmishek, 1982, 1988). They prolifically produce along sinuous trends where lithology changes – extending from the Omra Step, the southern Izhma-Pechora Depression and Upper Pechora Trough northward along the old Pechora-Kolva Aulacogen borders to a point south of the coastline (Figure 1). Facies are more marine eastward, and isopachs reflect pre-Late Devonian erosion within the Pechora-Kolva Aulacogen, where stratigraphic traps probably abound. Two fields are reported to produce from Middle Devonian strata within the Adzva-Varandey Zone (Petroconsultants,1996), although Ulmishek (personal communication, 1999) believes Middle Devonian strata to be absent there. Middle Devonian net reservoir thickness averages 13 meters, with a maximum of 114 meters.

Overall, Upper Paleozoic reservoirs are carbonates over sandstones by nearly 2:1 in volume of known ultimately recoverable reserves (Table 2). Net reservoir thicknesses average from 9 to 19 meters. Facies and play trends for these intervals are discussed and illustrated in Ulmishek (1982), Ulmishek (1988), Rostovshchikov and others (1991), Belyayeva (1992), Belyakov (1994), Zhemchugova and Schamel (1994), and Aleksin and others (1995). Tectonically controlled Upper Devonian and Lower Permian shelf-edge reefs comprise the most significant carbonate plays, and the Domanik source rock facies are the basinal age-equivalents to Upper Devonian reefs. Upper Devonian reservoirs occur in a similar area to Middle Devonian reservoirs – but with more abundance in the eastern part of the province – and Upper Devonian reef reservoirs also extend across the Khoreyver Depression. Upper Devonian reservoirs are all sandstone on the westernmost edge of the province, mostly carbonate in the eastern region, and mixed carbonate and siliciclastic across most of the Izhma-Pechora Depression and Pechora-Kolva Aulacogen.

Carboniferous reservoirs are limited in reserve-volume importance, but trend diagonally across the province from the southern Izhma-Pechora Depression and Omra Step region northeastward to the coastline at the Pechora-Kolva Aulacogen and Adva-Varandey Zone. Additional Carboniferous reservoirs have been discovered in the Kosyu-Rogov and Korotaikha foredeeps.

Lower Permian reservoirs delineate the largest area of any reservoir rock. They cover an onshore swath similar to the Carboniferous – from the southernmost tip of the province (mostly sandstone) to the most mountain-proximal foredeeps of Kosyu-Rogov and Korotaikha (carbonates) to the offshore (sandstone to the west, carbonate to the east). Kolguyev Island apparently marked the northeasternmost corner of the Paleozoic Timan-Pechora platform (Preobrazhenskaya and others, 1998).

Youngest Upper Permian and Triassic reservoirs (all sandstone and averaging 7 to 9 meters net thickness) are located on anticlines of the northern Pechora-Kolva Aulacogen, the northern Sorokin Swell and offshore on Kolguyev Island (Figure 1). More production approximately overlies the Middle Devonian fairway – along the western-Uralian foredeep margin from just north of the Omra Step northeastward to the foredeep junction with the Pechora-Kolva Aulacogen. Upper Permian and Triassic sandstone genesis ranges from fluvial-alluvial to marine in a SE-to-NW transect (Stupakova, 1992; Oknova, 1993; Kuranova and others, 1998). The entire north-northeastern part of the province – including the Pechora-Kolva Aulacogen, the Khoreyver Depression, the Korotaikha Trough, and the offshore extensions – could be prospective for Triassic stratigraphic and combination traps (Dedeev and others, 1994).

Reservoir Properties

Timan-Pechora siliciclastic reservoirs average 16% porosity and 154 md permeability, and carbonate reservoirs average 13% porosity and 208 md permeability (Petroconsultants, 1996) (Table 2).

For sandstones, *average* reservoir porosities range from a low of 11.5 % in the Lower Paleozoic reservoirs to a high of 22.5% in Triassic counterparts. The range of *maximum* sandstone reservoir porosity is 12% (Lower Paleozoic reservoirs) to 28% (Triassic reservoirs). For carbonates, *average* reservoir porosities range from a low of 9 % in the Lower Paleozoic reservoirs to a high of 15.8% in Lower Carboniferous counterparts. The range of *maximum* carbonate reservoir porosity is 10% (Lower Paleozoic carbonates) to 28% (Lower Permian reef reservoirs).

For sandstones, *average* reservoir permeabilities range from a low of 15 md in the Lower Paleozoic reservoirs to a high of 372 md in Upper Devonian counterparts. The range of *maximum* sandstone reservoir permeability is 15 md (Lower Paleozoic reservoirs) to 4000 md (Upper Devonian reservoirs). For carbonates, *average* reservoir permeabilities range from a low of 63 md to a high of 930 md, both in Lower Paleozoic reservoirs. The range of *maximum* carbonate reservoir permeability is 80 md (Lower Paleozoic carbonates) to 1200 md (Upper Devonian reef reservoirs).

Hercynian orogenic siliciclastics are lithic-rich; thus, Triassic sandstones have somewhat lower average (75 md) and maximum (340 md) reservoir permeabilities than Paleozoic sandstones. Paleozoic carbonate reef reservoirs contain 53% of known ultimate recoverable reserves (Table 2). Upper Devonian shelf-edge reef fronts are commonly dolomitized, and best reservoir properties are located near the slope break. Kuznetsov (1997) provides the example of Pashshor field where net/gross pay ratios vary from 67-90% in reef-front facies to 13-39% in back-reef facies. In contrast, Permian reefs have best primary porosity preserved in stacked lenticular zones at the reef centers.

SEAL ROCK

A Late Paleozoic humid climate in this region contributed to the development of local and regional shale seals rather than evaporite seals (Kuznetsov, 1997). Upper Devonian (Lower Frasnian) Kynov and Sargay transgressive marine shales are commonly tens-of-meters thick. The Kynov Shale has a regionally unconformable relationship with underlying strata of various ages over most of the Timan-Pechora Basin Province (Ulmishek, 1982). Upper Frasnian to Tournaisian Domanik source-rock facies and carbonates with anhydrite beds, as thick as several hundred meters together, also provide good sealing potential.

Lower Permian (Artinskian to Kungurian) marine shales and evaporites range to hundreds of meters in thickness. Salt is present only in the southern Upper Pechora Trough. At Vuktyl field, anhydrite seals a 1.4-km gas column equal to the structural closure for the field (Sobornov and Rostovshchikov, 1996).

Syn-Hercynian Upper Permian and Triassic siliciclastics also contain adequate seals, particulary in marine and coastal shales (Zakharov and Kulibakina, 1997). Both the upper member of the Lower Triassic Charkabozh Formation and offshore marine shales of Upper Jurassic to Lower Cretaceous age also are regional seals to several hundred meters in thickness (Oknova, 1993).

ASSESSMENT UNITS

The Domanik-Paleozoic total petroleum system is somewhat smaller than the Timan-Pechora Basin geologic province (Figure 5), with 18.8% of the province excluded (84,000 sq km – all northern offshore waters). Three assessment units are designated to assess resource potential – N.W. Izhma-Pechora (#10080101), Main Basin Platform (#10080102), and Foredeep Basins (#10080103). For the purposes of this resource assessment, no field-growth function will be utilized for data from this province because of some known cases of over-reporting of reserves (G.F. Ulmishek, personal communication).

N.W. Izhma-Pechora Assessment Unit #10080101

The northwestern portion of the Izhma-Pechora Depression (Figures 1 and 5) is a hypothetical assessment unit. It has no known fields and is outside of the known area of active source rock. N.W. Izhma-Pechora comprises 19.5% of the total petroleum system and is approximately 70,600 sq km in size, with 10.5% of that area offshore. Seventy-five onshore wells have tested its area. Risks are increased relative to the Main Basin Platform (discussed below) for source rock presence, migration routes, and the timing of trap formation relative to migration.

Main Basin Platform Assessment Unit #10080102

This major producing area in the total petroleum system includes the original stable platform areas of the province and the old aulacogen region(s) (Figures 1 and 5). It is an established assessment unit. The Main Basin Platform comprises 56.5% of the total petroleum system and is approximately 205,100 sq km in size, with 16.2% of that area offshore. It is distinguished from the following Foredeep Basins (#10080103) assessment unit because of differences in burial history, trap types, and timing of trap formation as related to generation and migration/remigration (Figure 6).

Most significant structures onshore have been tested, but offshore areas are largely unexplored. A greater emphasis on stratigraphic traps – alone or in combination with structural enhancement – is expected for future field development and reserve additions, especially for the onshore areas. The following major trap types are discussed in Ulmishek (1982) and Dedeev and others (1994). Lower Paleozoic carbonate and siliciclastic rocks generally have an angular configuration, updip to the west, beneath the regional pre-Middle Devonian unconformity. Overlying Middle Devonian sandstones are eroded by the post-Middle Devonian unconformity and preserved in SSW-NNE trends that weave across this assessment unit (Figure 55 in Ulmishek, 1982).

Similarly, Upper Devonian to Tournaisian and Lower Permian carbonate build-ups have delineated shelf-edge trends (Figure 56 in Ulmishek, 1982; Figure 1 in Rostovshchikov and others, 1991; Figure 1 in Belyayeva, 1992; Figure 4 in Belyakov, 1994; Figure 2 in Zhemchugova and Schamel, 1994; Figure 1 in Aleksin and others, 1995 ; and Figure 1 in Ivanova, 1997). Finally, Permo-Triassic stratigraphic and combination traps are both known and further expected.

Foredeep Basins Assessment Unit #10080103

The Foredeep Basin assessment unit is also established with production and comprises 24% of the total petroleum system. It is approximately 87,100 sq km in size, with 8.7%

of that area offshore. Trap styles in this assessment unit will be dominated by Uralian and Pay Khoy thrusted closures without surface expression, and sour gas is expected to constitute a large portion of the resource base. Not included in this assessment process are unconventional gas accumulations (Ben Law, U.S. Geological Survey, personal communication) in Artinskian and Kungurian coaly siliciclastics of the foredeep region.

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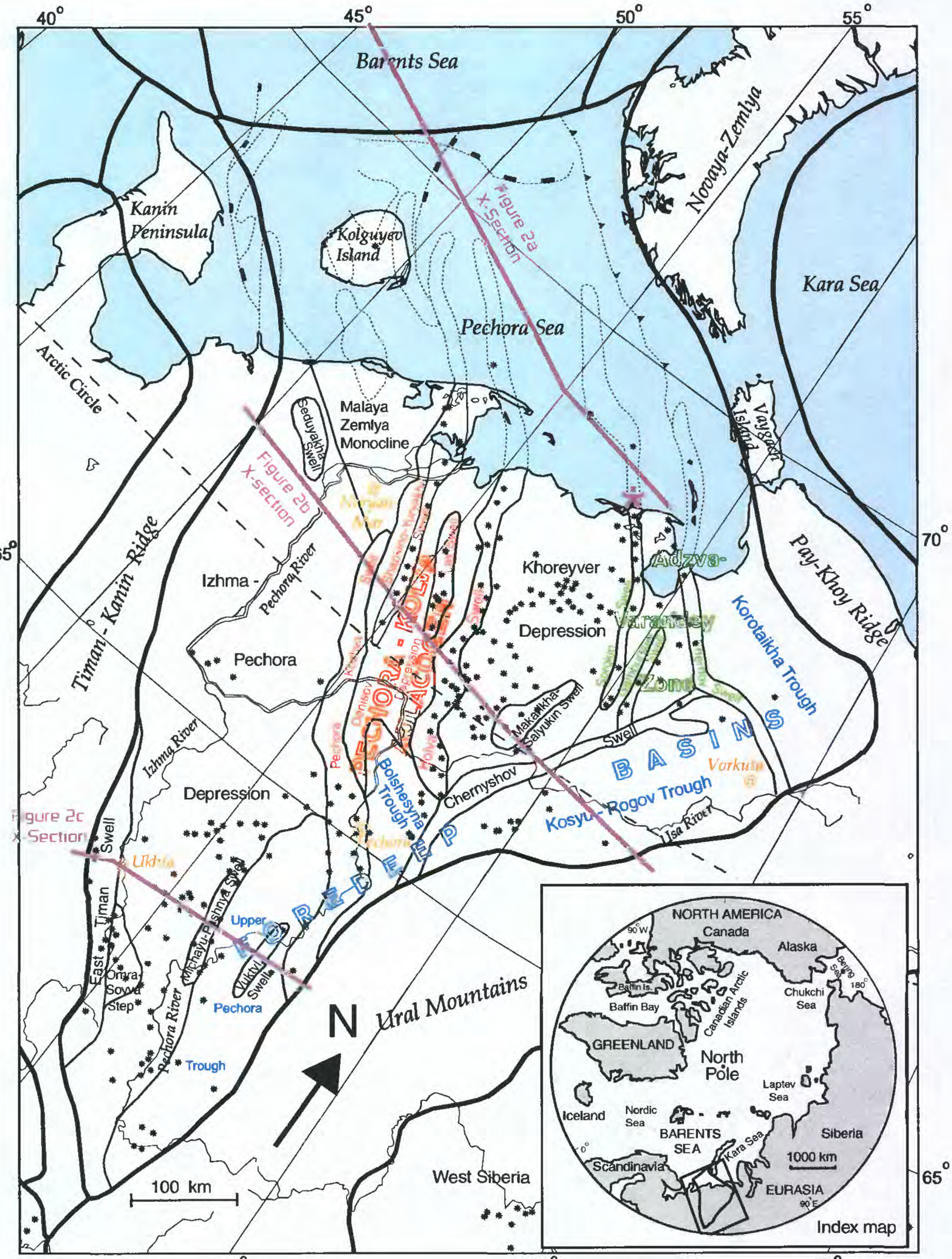


Figure 1. Location map for Timan-Pechora Basin and Province.

EXPLANATION

- Rivers
- Shoreline
- Province Boundary
- Country Border
- * Field Centerpoints
- Towns
- Normal Faults
- Thrust Faults
- Offshore Highs
- Location of Figure 8 burial history plot

Structural regions after Ulmishek, 1982; Lobkovsky and others, 1996; and Ivanova, 1997.

Figure 2a. Timan-Pechora offshore structural cross section (after Ostisty and Fedorovsky, 1993).

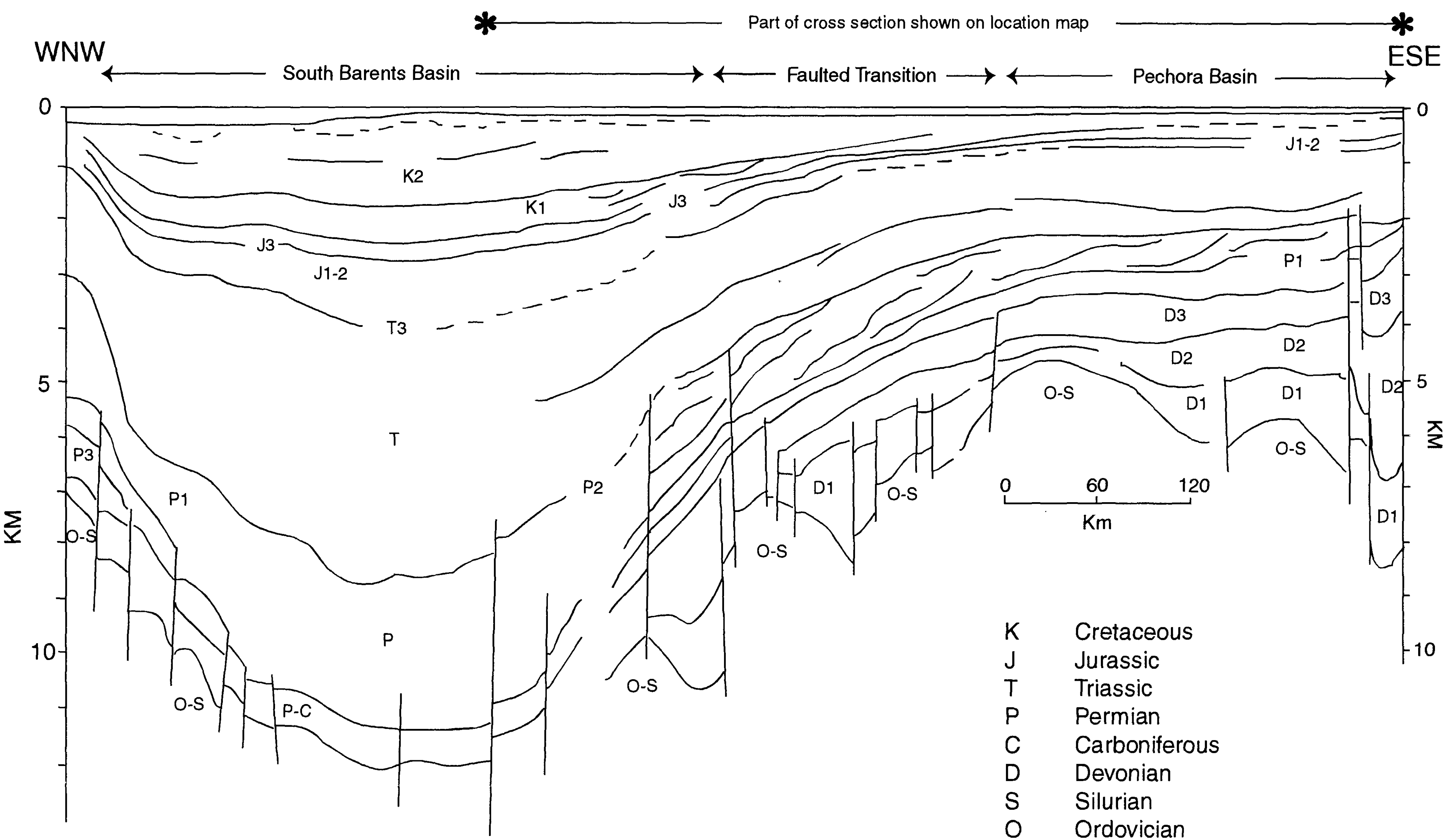


Figure 2b. Timan-Pechora northern onshore structural cross section (after Ulmishek, 1982).

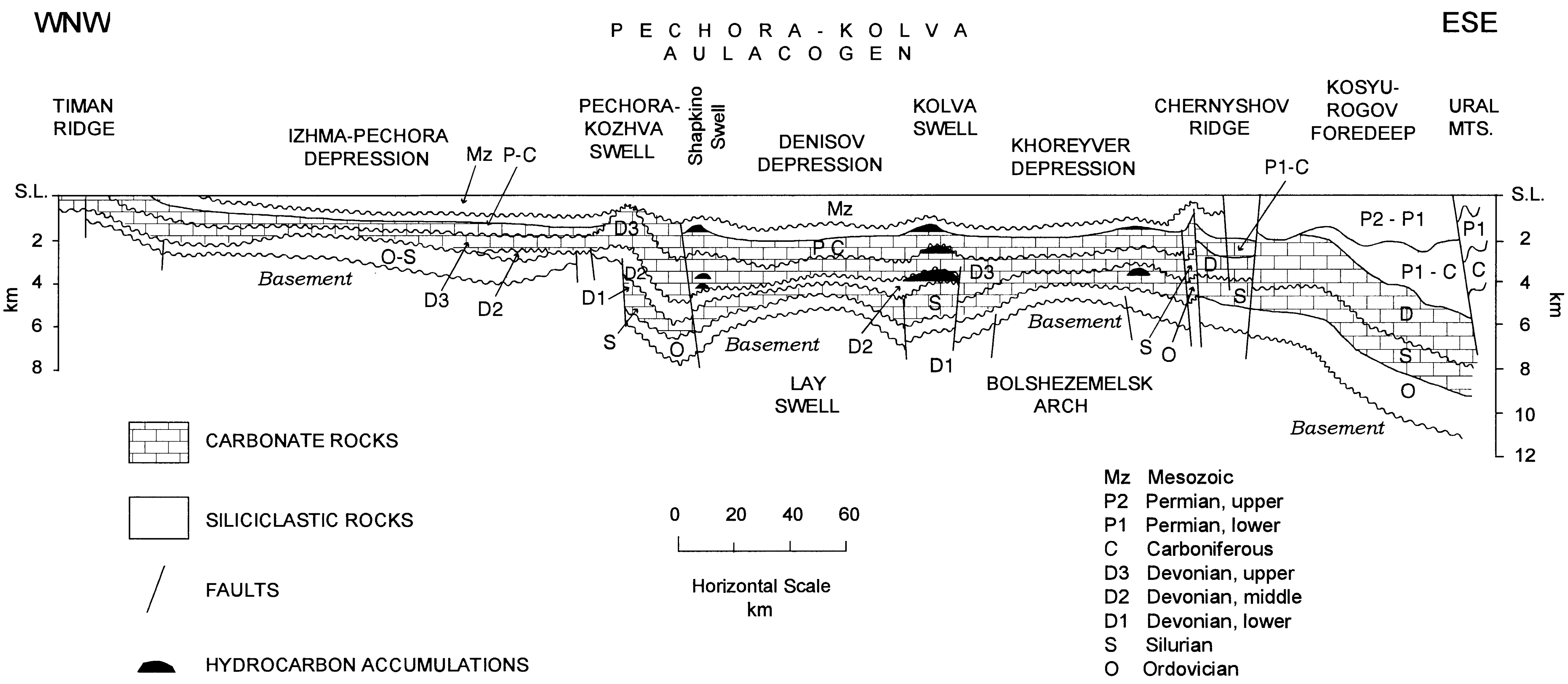


Figure 2c. Timan-Pechora southern onshore structural cross section (after Dedeev and others, 1994).

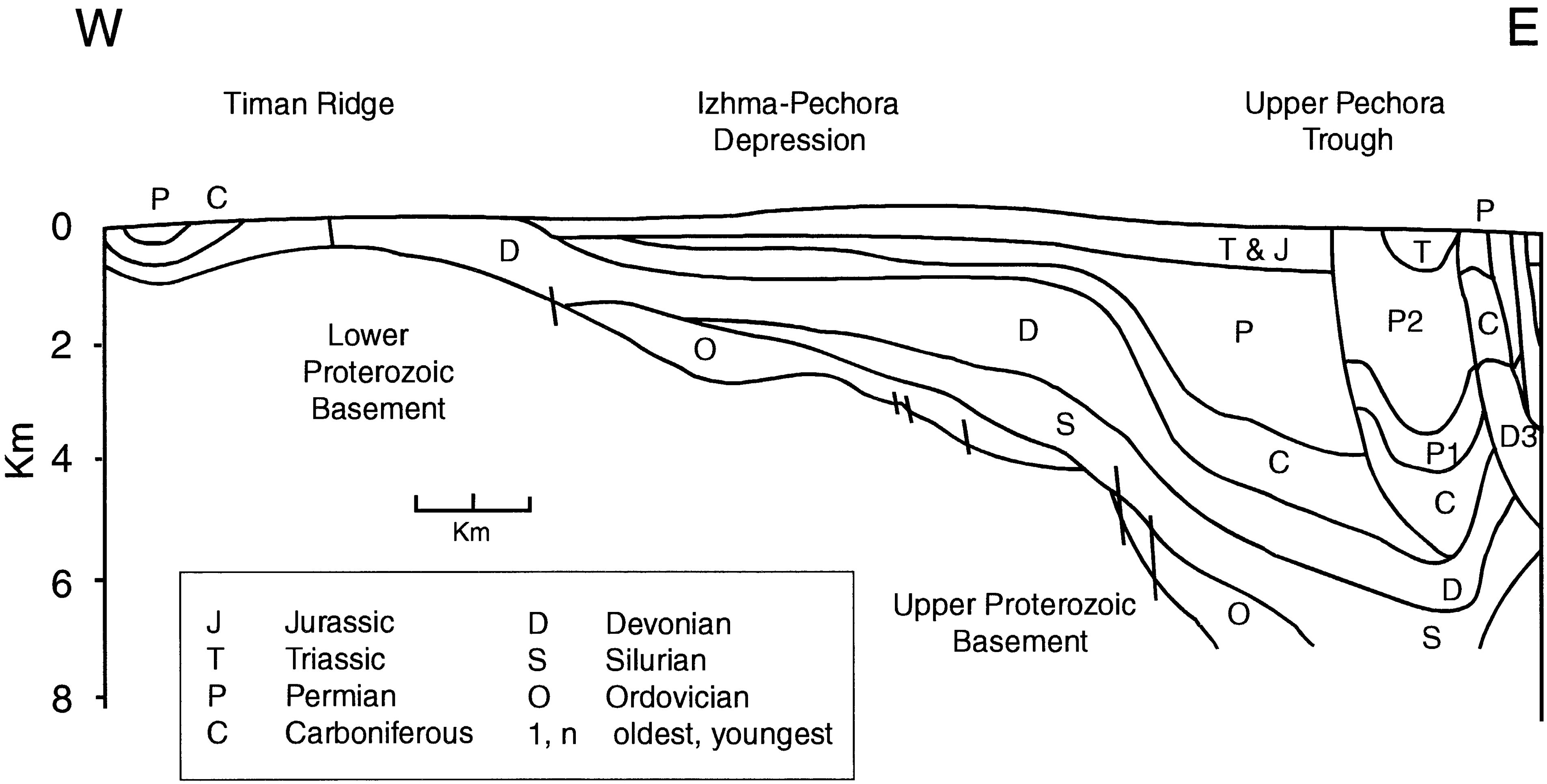


Figure 3. Chart of generalized stratigraphy for the Timan-Pechora Basin Province.

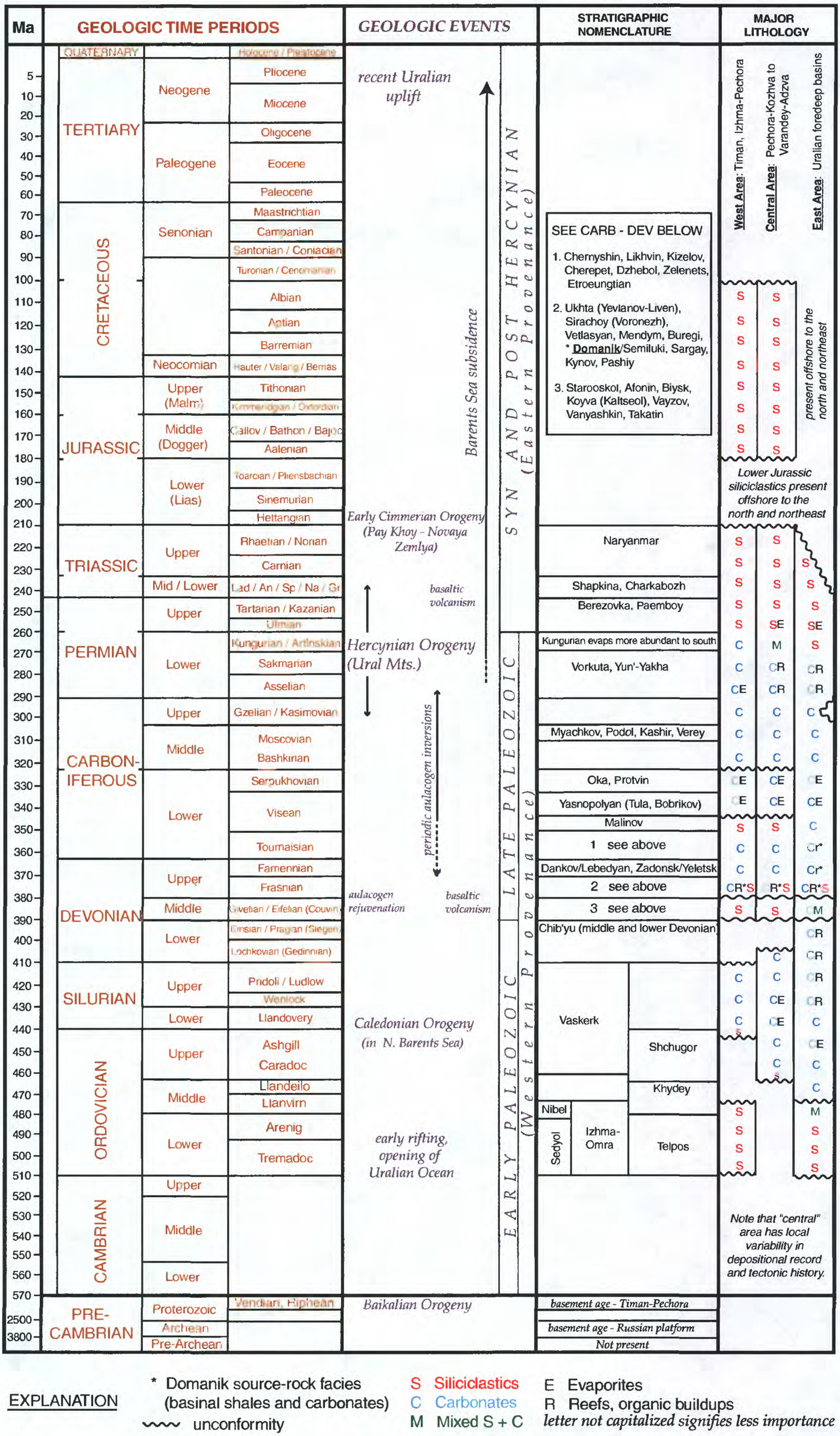
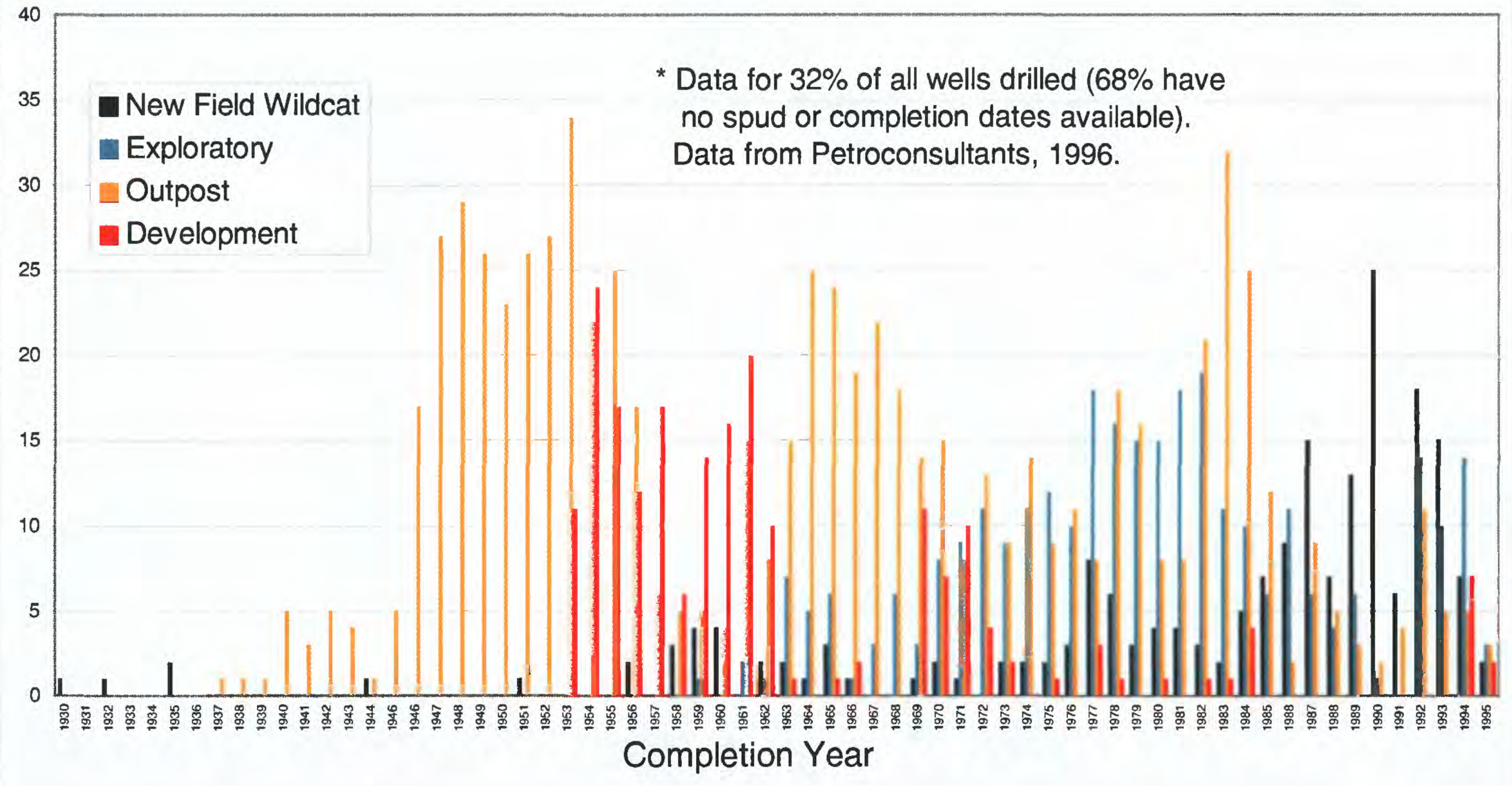


Figure 4. Numbers of Wells Drilled in theTiman-Pechora Basin Province



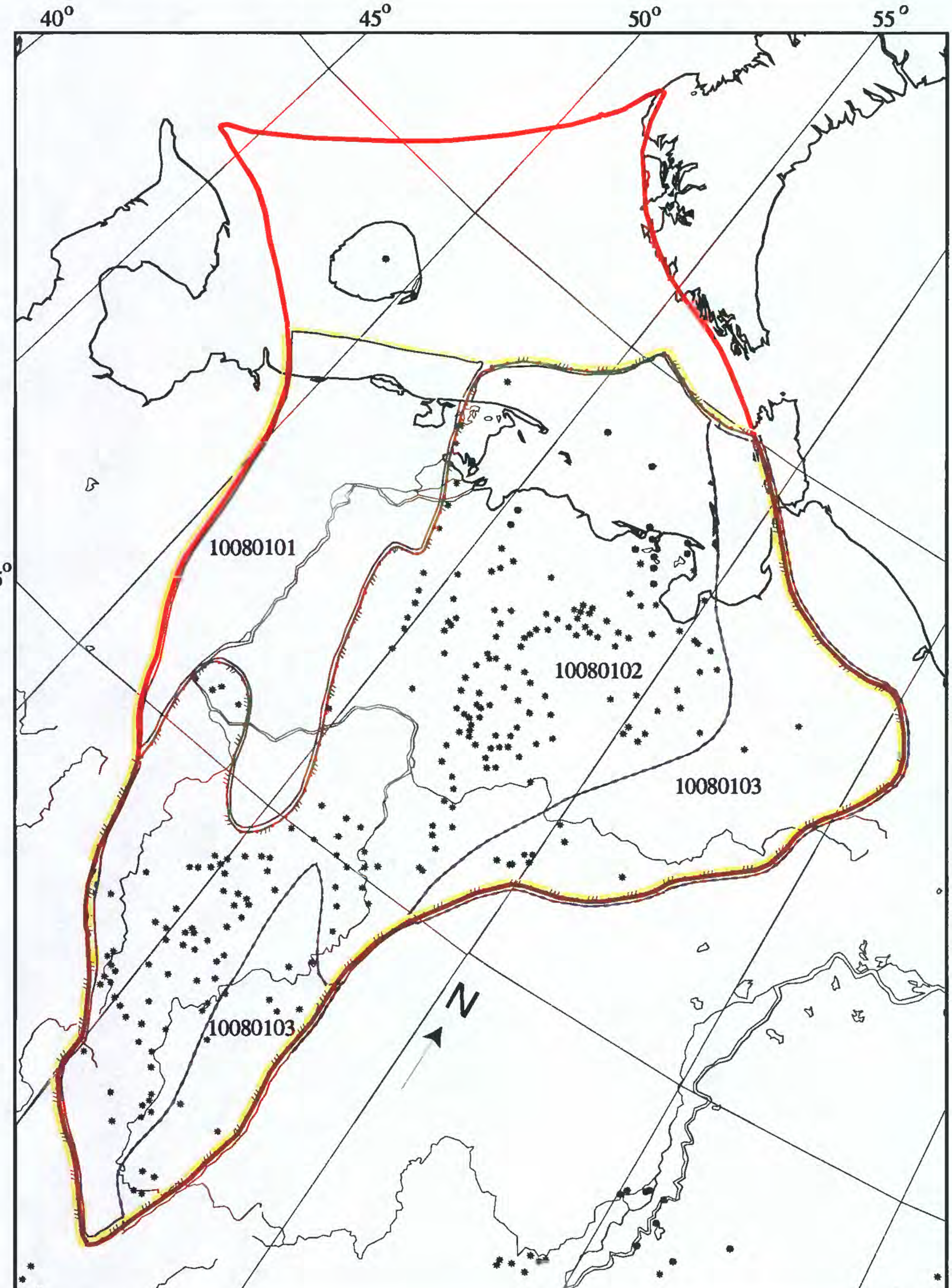


Figure 5. Map of petroleum system and assessment units for Timan-Pechora Basin Province. The 3 assessment units are discussed in the text.

EXPLANATION

- Rivers
- Coastline
- Province boundary
- Country boundary
- Field Centerpoints

10080101 Assessment Units

Minimum petroleum system outline

Total petroleum system outline

Area of active source rock
Tics marks on side of presence

Figure 6. Total petroleum system events chart (onshore area).

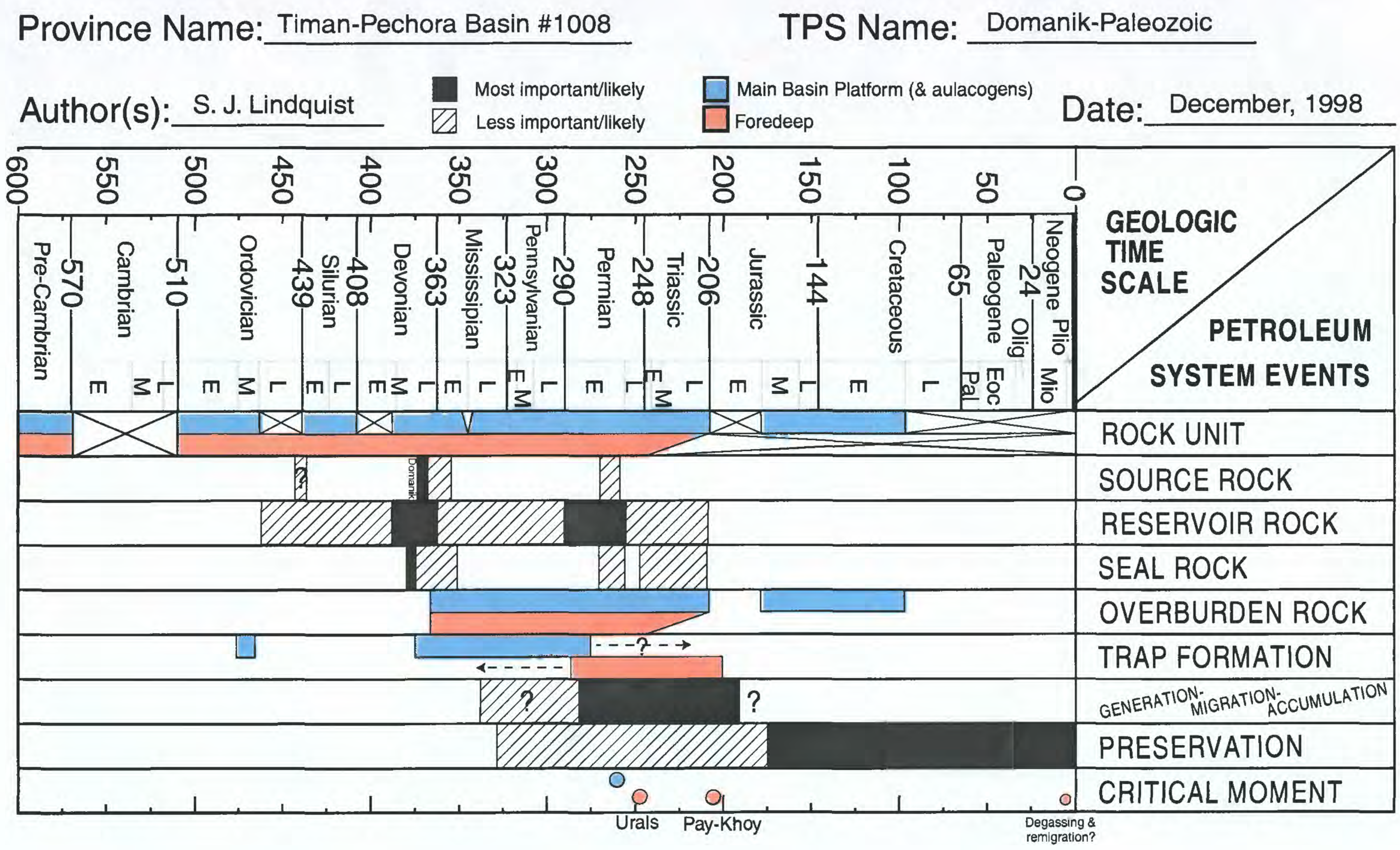


Figure 7a. Burial history chart for somewhere in the Izhma-Pechora Depression (after Pairazian, 1993). Note that the proposed Carboniferous maturation is earlier than most other authors believe.

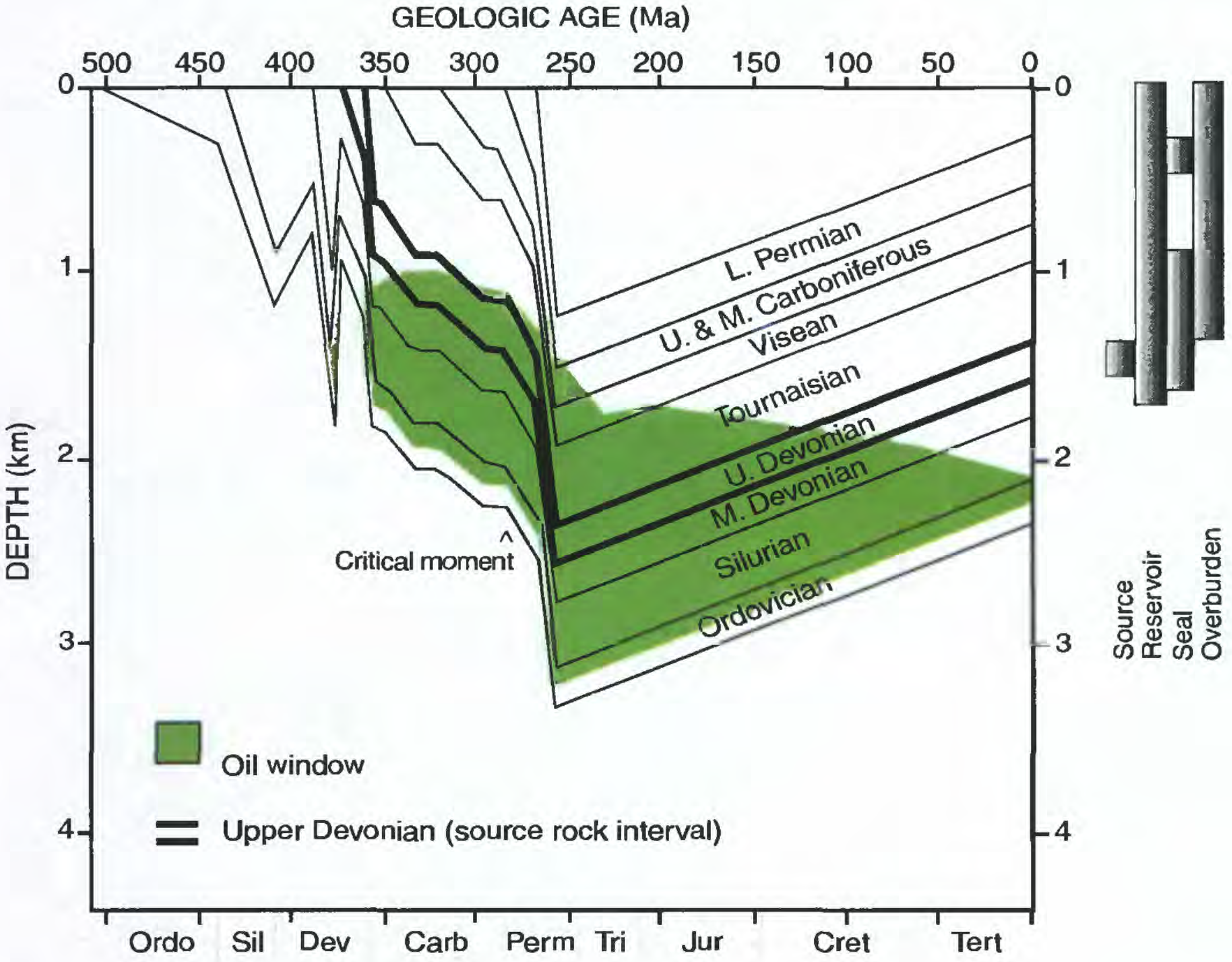


Figure 7b. Burial history chart for somewhere on the Malaya Zemlya monocline (coastal area) (after Pairazian, 1993). Note that the proposed Carboniferous maturation is earlier than most other authors believe.

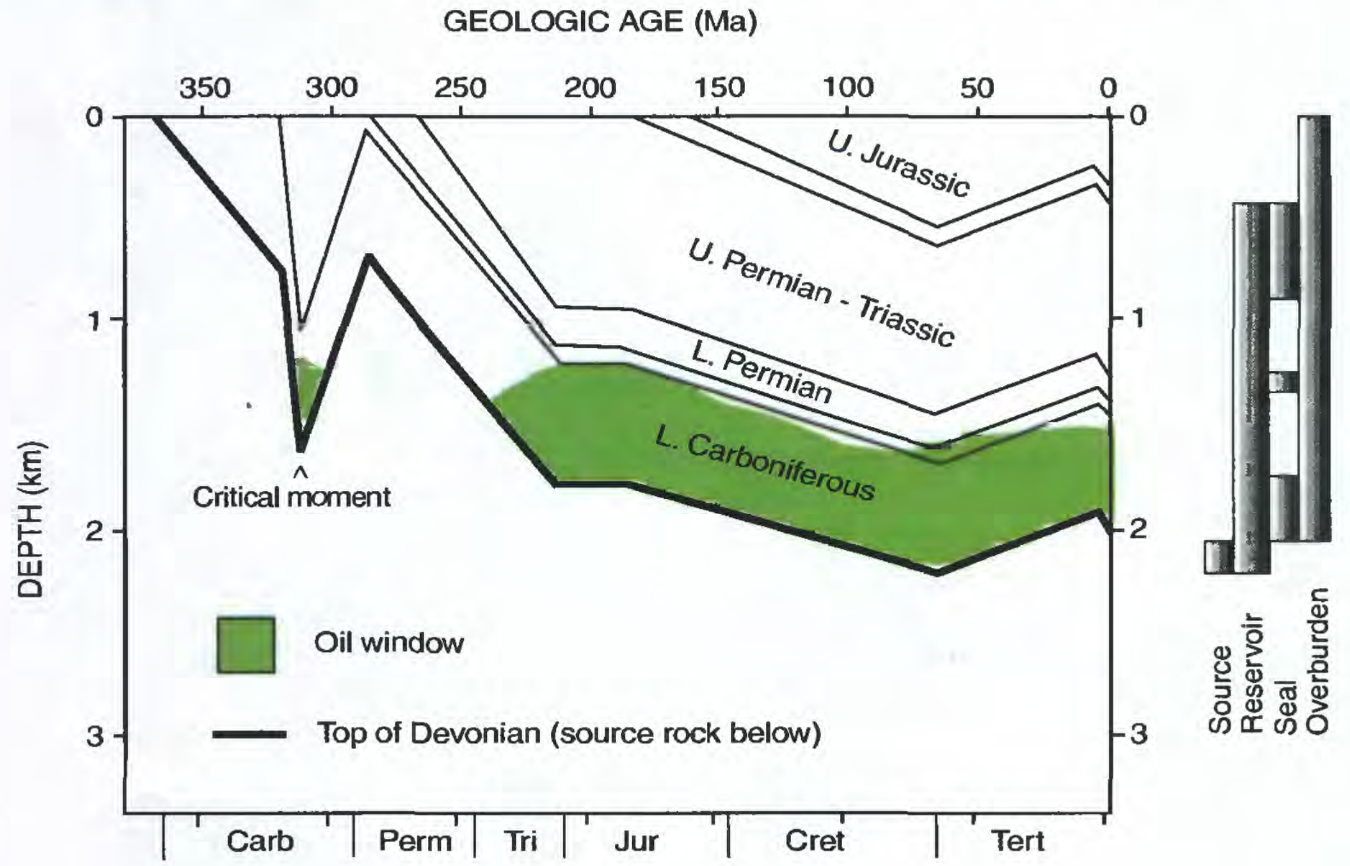


Figure 7c. Burial history chart for somewhere in the Pechora-Kolva Aulacogen (after Pairazian, 1993). Note that the proposed Carboniferous maturation is earlier than most other authors believe.

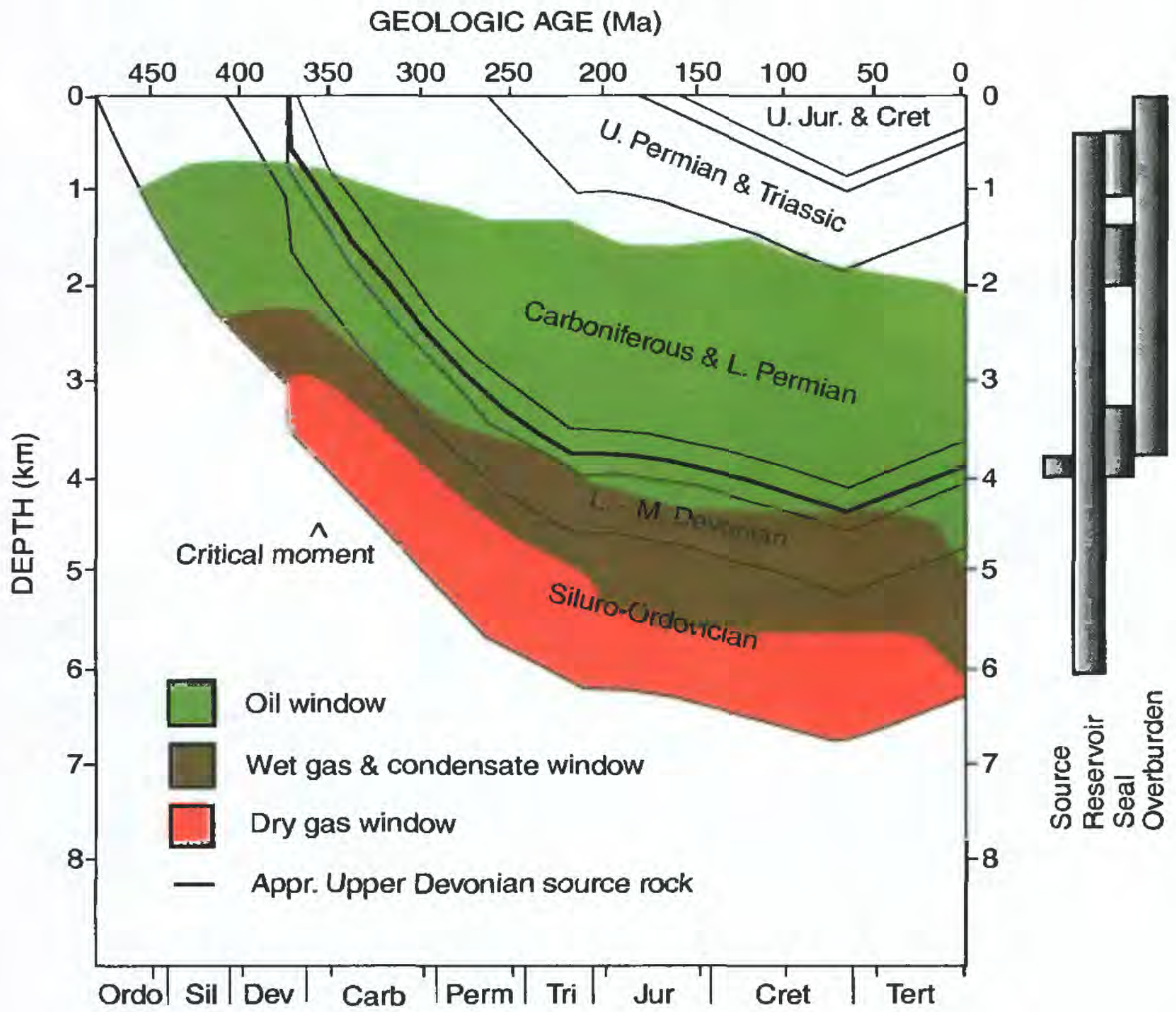


Figure 7d. Burial history chart for somewhere in the Khoreyver Depression (after Pairazian, 1993). Note that the proposed Carboniferous maturation is earlier than most other authors believe.

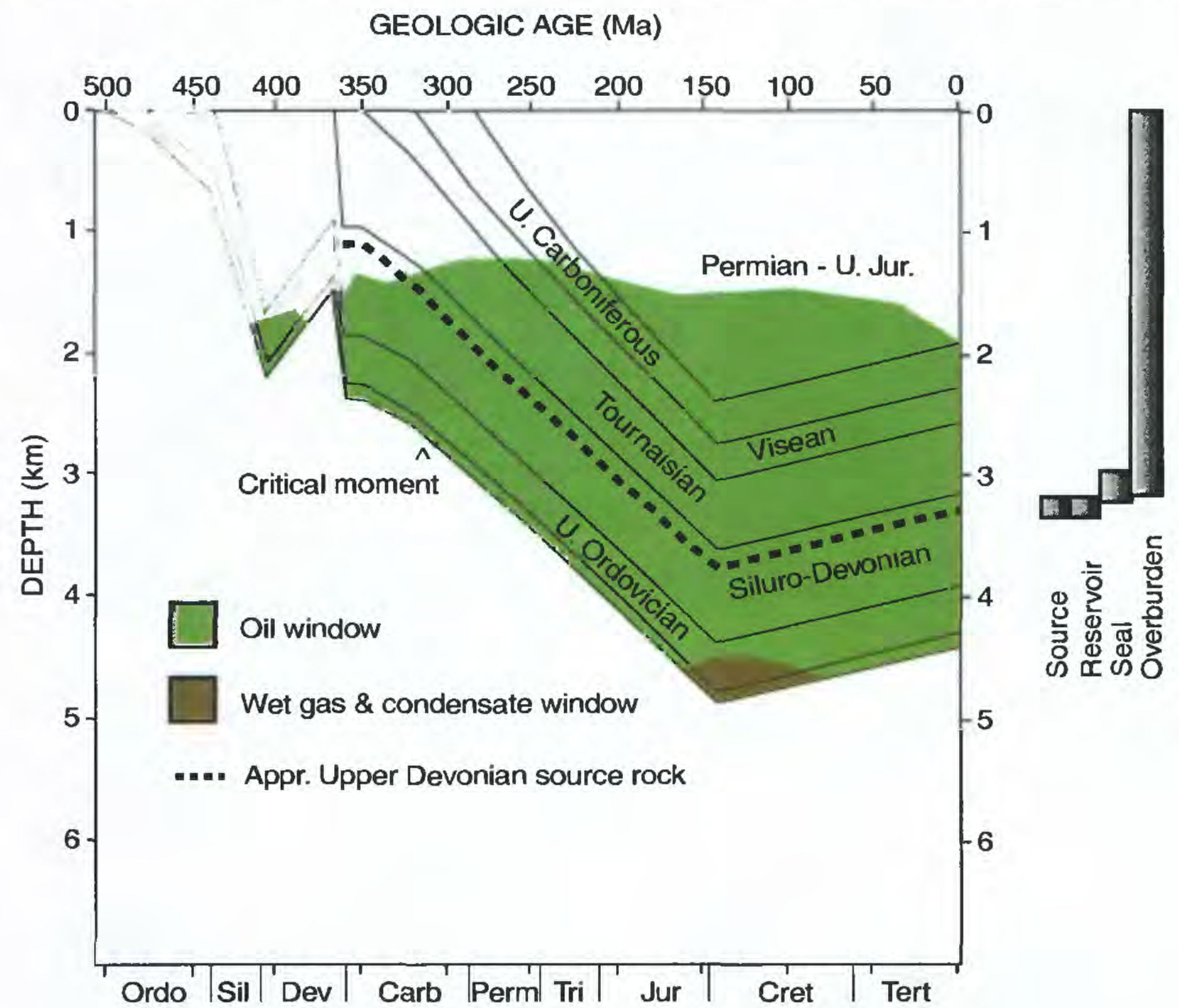


Figure 7e. Burial history chart for somewhere in the Varandey-Adzva Zone (after Pairazian, 1993). Note that the proposed Carboniferous maturation is earlier than most other authors believe.

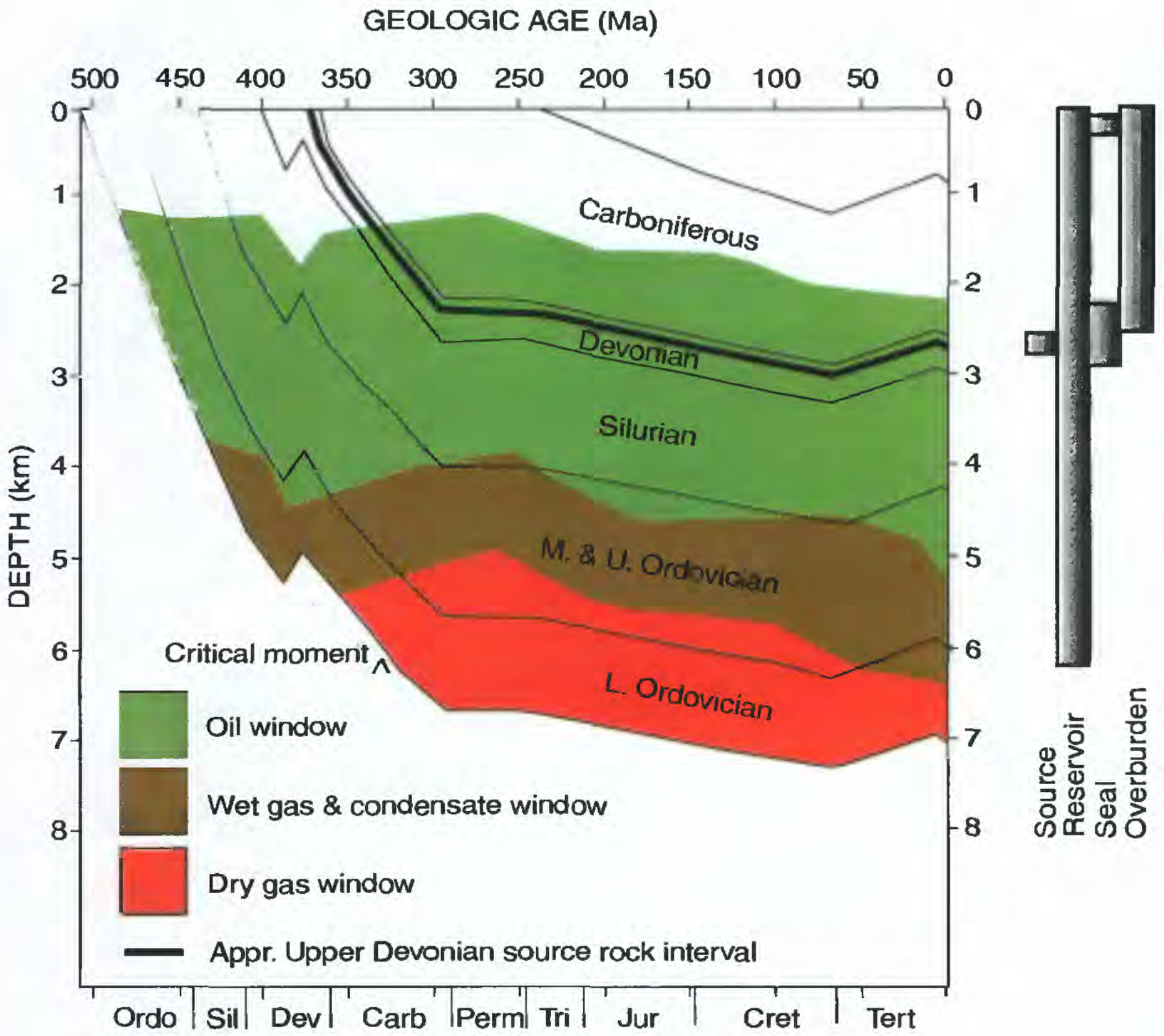


Figure 7f. Burial history chart for somewhere in the Uralian foredeep region (after Pairazian, 1993). Note that the proposed Carboniferous maturation is earlier than most other authors believe.

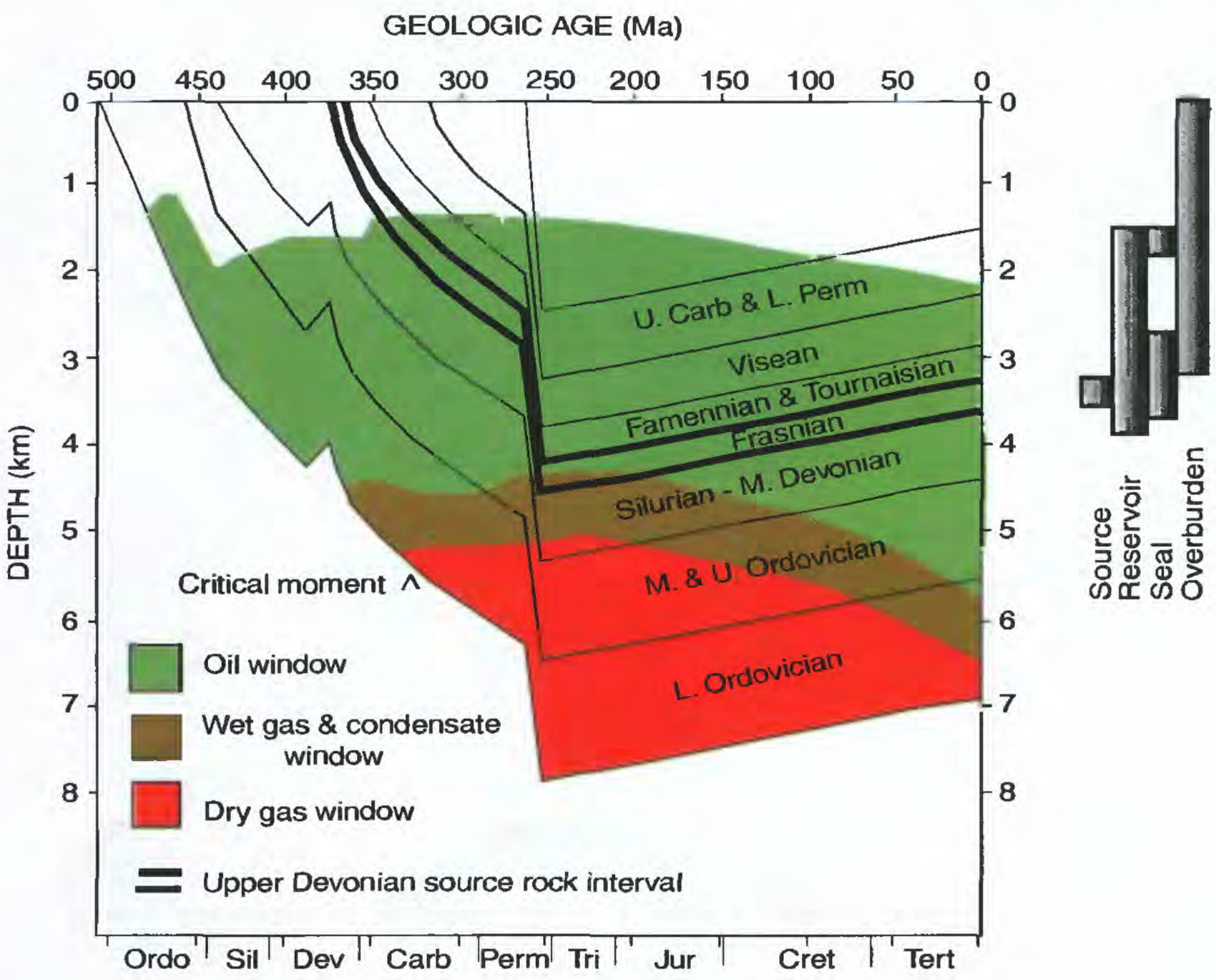


Figure 8. Burial history chart for Sorokin Swell coastal area showing Permo-Triassic oil generation (Ro 0.6 % and Ro 0.8 % noted) (after Martirosyan and others, 1998). Location is shown on Figure 1.

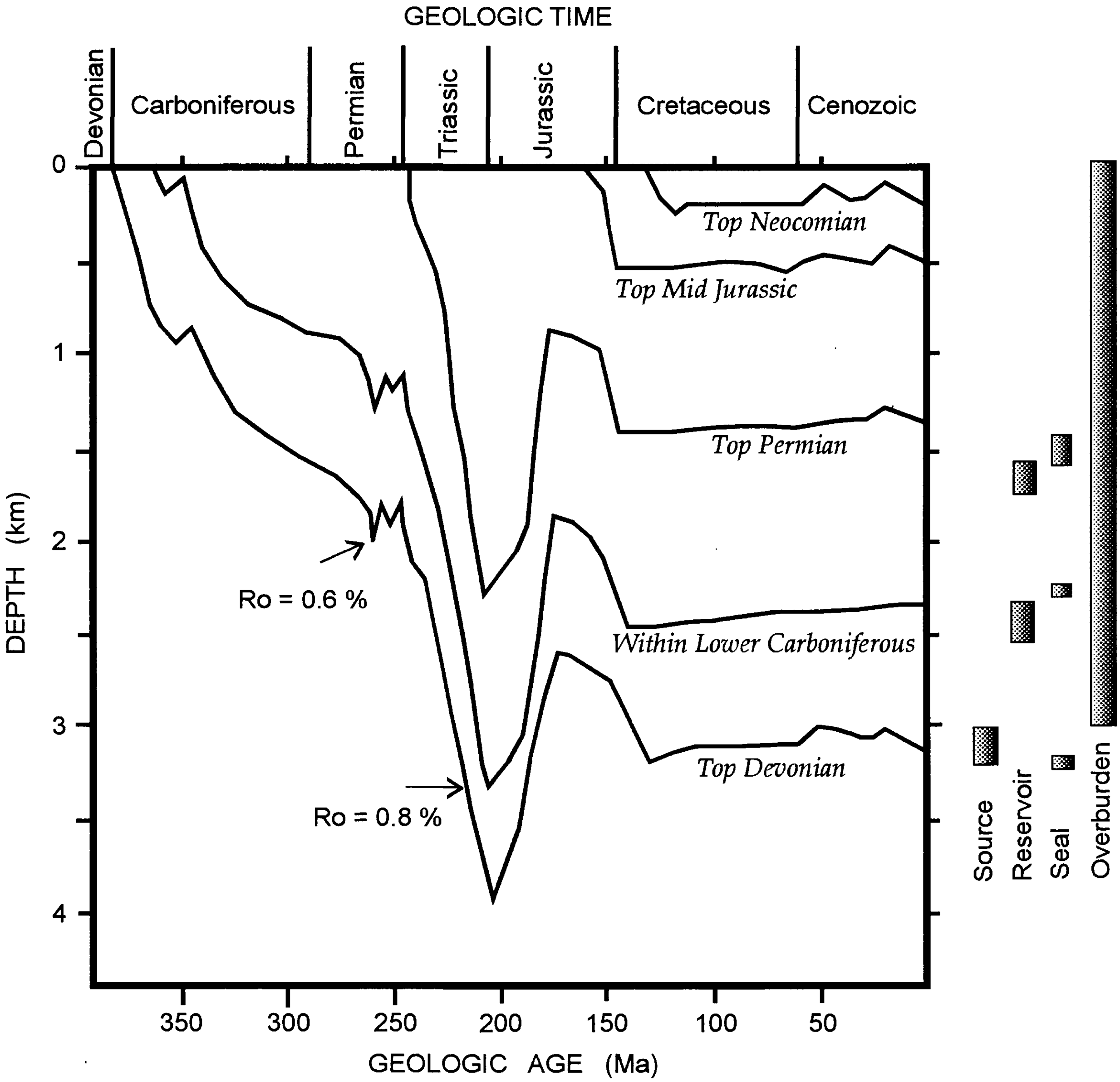


Table 1. Timan-Pechora Basin Province producing fields of the Domanik-Paleozoic total petroleum system (alphabetical order).
(G = gas, O = oil, C = condensate)

Field	Type	Disc. Year	Comments	Field (continued)	Type	Disc. Year	Comments
A. Titov (Olen'ya)	Oil	1987	*	Pechora-Gorod	GC & O	1962	
Adzva East *(Vostochnaya)*	Oil	1990		Pechora-Kozhva	GC & O	1962	
Andronovskoye	Oil			Peschano-Ozerskoye	OG & C	1982	#
Aranetskoye (Aranets)	O & G	1964		Podver'yu	Oil	1987	
Ardalin	Oil	1988		Pokchinskoye (Pokcha)	Oil	1959	
Aress	Oil	1987		Pomorskoye	G & C	1985	
Aress North *(Severnoye)*	Oil	1986		Pravoberezhnoye (Komi)	Gas	1958	
Aress West *(Zapadnoye)*	Oil	1987		Priluskoye-Pal'yu	G & C	1978	
Ayyuva	Oil	1965		Prirazlomnoye (Pechora Sea)	O & G	1989	
Bad'y North *(Severnyy)*	Oil	1991		Pursamyl	Gas	1990	
Bad'yu South *(Yuzhnyy)*	Oil	1993		Pyusey	Oil	1992	
Bagan (Bagan-Yuvom)	Oil	1984		Pyzh'yel (Pyzh'yelskoye)	Oil	1981	
Bagan North *(Severnyy)*	Oil	1986		Pyzh'yel East *(Vostochnyy)*	OG & C	1993	
Bagan East *(Vostochnyy)*	Oil	1988		Pyzh'yel South *(Yuzhnyy)*	Oil	1981	
Bagan South *(Yuzhnyy)*	Oil	1985		Ras'yu	Oil	1987	
Beluzeyskoye	O & G	1981		Rassokha	G & C	1968	
Beregovoye (Timan-Pechora)	Oil	1988		Rogozinskoye	Oil	1991	
Bezymyannoye (Komi)	Oil	1991		Rogozinskoye East *(Vostochnoye)*	Oil	1991	
Bol'shelyaga	G & C	1987		Rogozinskoye West *(Zapadnoye)*	Oil	1994	
Borovoye	Oil			Roman Trebs	Oil	1987	*
Charkayeskoye East *(Vostochnoye)*	Oil	1985		Romanyel (Romanyelskoye)	G & C	1985	
Chedtyy	Oil	1987		Rozda	Gas	1944	
Chernorechenskoye	Gas	1979		Salyuka (Salyukinskoye)	Oil	1971	
Cherpayu	Oil	1984		Sandivey	Oil	1981	
Chibyu (Chibyuskoye)	Oil	1930		Sandivey West *(Zapadnyy)*	Oil	1981	
Chikshino	Oil	1989		Saremboy	Oil	1977	
Dinyel	Oil	1989		Saremboy North *(Severnyy)*	Oil	1978	
Dyusushev	Oil	1989		Sarutayuskoye (Sarutayu)	Oil	1986	
Dzh'yer	O & G	1963		Savinobor	Oil	1963	
Dzhebol	G & C	1956		Savinobor North *(Severnyy)* (Severo-Savinoborsk)	Oil	1963	
Dzhebolskoye South *(Yuzhnoye)*	G & C	1960		Savinobor East *(Vostochnoye)*	Oil	1962	
Gulyayevskoye North *(Severnoye)*	GC & O	1986		Sed'yol	Gas	1935	
Inta (Intinskoye)	G & C	1977		Sed'yol North *(Severnyy)*	Gas	1951	
Inta South *(Yuzhnaya)*	Gas			Sedyaga	Oil	1980	*
Inta West *(Zapadnaya)*	Gas	1977		Shapkina	GC & O	1966	
Inzyrey	Oil	1990		Shapkina South *(Yuzhnaya)*	OG & C	1969	
Irayel	Oil	1978		Shorsandivey	Oil	1986	
Isakov (Komi)	Oil	1962		Sikhorey	Oil		
Izhemka-Tarkskoye	O & G	1984		Sikhorey North *(Severnyy)*	Oil	1990	
Izkos'gorinskoye West *(Zapadnoye)*	G & O	1956		Sikhorey East *(Vostochnyy)*	Oil	1990	

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Kamenskoye (Komi)	Oil	1977		Soples West *(Zapadnyy)* (Zapadno-Soplesskoye)	GC & O	1974	
Khar'yaga	Oil	1977		Sosnovskoye (Izhma-Pechora)	Oil	1982	
Khar'yaga North *(Severnaya)*	Oil	1977		Sotchem'yu	Oil	1978	
Khar'yaga East (Vostochnaya)	Oil	1985		Sotchem'yu East *(Vostochnyy)*	Oil	1989	
Khar'yaga South *(Yuzhnaya)*	Oil	1977		Sredne-Kharyaga	Oil	1988	
Khasyrey	Oil	1989		Sredne-Komandirshor	Oil	1990	
Khatayakha West *(Zapadnaya)*	Oil	1989		Sredne-Sarutayuskoye (Sredne-Sarutayu)	Oil	1984	
Khayakha North *(Severnaya)*	Oil	1989		Sredne-Sercheyyu	G & O	1970	
Khoreyver East *(Vostochnyy)*	Oil	1985		Sredneye Kos'yu	Oil	1992	
Khosedayu North *(Severnyy)*	Oil	1984		Srednyaya Makarikha	O & G	1970	
Khosedayu West *(Zapadnyy)*	Oil	1988		Stepkovozh South *(Yuzhnyy)*	Oil	1990	
Khosolta	Oil	1986		Subor	Oil	1987	
Khudoelskoye	Gas	1980		Sunayel'	Oil	1991	
Khylchuyu	OG & C	1977		Syninskoye (Synya)	Oil	1974	
Khylchuyu South *(Yuzhnoye)*	O & G	1981		Synya South *(Yuzhnaya)*	Oil	1976	
Kochmesskoye (Kochmes)	OG & C	1979		Syurkharata	Oil	1987	
Kodach	Oil	1989		Syurkharata South *(Yuzhnaya)*	Oil	1987	
Kolva	Oil	1986		Tabrovo-Yakha	Oil	1993	
Kolva East *(Vostochnaya)*	Oil	1987		Talotayakha	Oil	1985	
Komandirshor	Oil	1986		Talyyyu	Oil	1988	
Komandirshor North *(Severnyy)*	Oil	1987		Tarkskoye	Oil	1988	#
Komandirshor West *(Zapadnyy)*	OG & C	1993		Tebuk South *(Yuzhnyy)*	Oil	1978	
Korovinskoye	G & C	1980		Tebuk West *(Zapadnyy)* (Zapadno-Tebukskoye)	Oil	1959	
Korovinskoye North *(Severnoye)*	G & C	1980		Tedyn	Oil	1989	
Kos'yu North *(Severnoye)* (Sredneye Kos'yu)	Oil	1992		Terekhevey South *(Yuzhnyy)*	Oil	1990	
Kostyuk	O & G			Toboy	Oil	1984	
Kozhia	Gas	1980		Toravey (Toraveyskoye)	Oil	1977	
Kozhva North *(Severnaya)* (Severo Kozhvinskoye)	Oil	1977		Toravey South *(Yuzhnyy)* (Yuzhno Toravey)	Oil	1978	
Kozlayu	G & C	1981		Troitsko-Pechorskoye	O & G	1959	
Kumzhinskoye (Kumzha)	G & C	1975		Turchaninov	Oil	1990	
Kur'ya	G & C	1960		Turchaninov West *(Zapadnyy)*	Oil	1992	
Kush-Kodzh (Kushkodzhskoye)	Gas	1949		Turyshev	Oil	1988	
Kykayel	Oil	1976		Tybyuskoye	Gas	1959	
Kyrtashorskoye (Kyrtashor)	Gas	1980		Ufim	Oil		
Kyrtayel (Kyrtayel'skoye)	OG & C	1969		Ugol'noye	Gas		
Kyrtayel South *(Yuzhnyy)*	O & G	1976		Urernyrd	Oil	1988	
Labogan (Laboganskoye)	Oil	1978	*	Usa	Oil	1963	
Lapkotyn (Lapkotynskoye)	Oil	1991		Usino-Kushshor (Usino-Kushshorskoye)	Oil	1985	
Layavozh (Layavozhskoye)	GC & O	1969		Ust-Pyaiyuskoye (Ust-Pyaiyu)	Oil	1985	
Lekkemskoye	G & O	1965		Ust-Rasyu	Oil	1989	
Lekker	Oil	1990		Ust-Talota	Oil	1987	
Lekkeyyaga	Oil	1985		Ust-Tsilma	Oil	1989	
Lekkeyyaga West *(Zapadnaya)*	Oil	1987		Vaganskoye	Oil	1982	
Lekkharyaga	Oil	1985		Van'yu	Oil	1978	
Lem'yu	Oil	1958		Vaneyvisskoye	OG & C	1973	
Lemvinskoye (Lemva)	Gas	1985		Varandey	Oil	1975	

Lemyu Vostochnoye	Oil			Varandey More	Oil	1995	
Lenavozh	Oil	1975		Varknavtovskoye (Varknavt)	Oil	1987	
Listvenich South *(Yuzhnyy)*	Oil	1987		Vasilkovo	G & C	1970	
Luza (Luzskoye)	Oil	1965		Velyuskoye (Velyu)	Oil	1980	
Lydushor	Oil	1989		Verkhne Amdermayel	G & C	1986	
Lyzha-Yuzhnaya	Oil	1987		Verkhne Chut'	O & G	1984	
Madagashor	Oil	1993		Verkhne Makarikha	Oil	1992	
Makaryel	Oil	1989		Verkhne-Grubeshor	Oil	1969	
Masteryel	Oil	1987		Verkhne-Kharitsey	Oil		
Masteryel North *(Severnyy)*	Oil	1992		Verkhne-Kolva	Oil	1986	
Medyn	Oil	1990		Verkhne-Kos'yu	Oil	1986	
Mezhdurechenskoye (Arkhangel'sk)	Oil	1990		Verkhne-Laya	Oil	1990	
Michayu	Oil	1961		Verkhniy Vozey	Oil	1986	
Michayu North *(Severnyy)*	Oil	1992		Verkhnyaya-Omra (Verkhne-Omrinskoye)	G & O	1948	
Mishparma	G & C	1986		Veyaka	Oil	1986	
Mishvan	G & O	1987		Veyaka East *(Vostochnaya)*	Oil	1990	
Musyurshor	Oil	1983		Veyaka South *(Yuzhnaya)*	Oil	1987	
Myadsey	Oil	1986		Veyaka West *(Zapadnaya)*	Oil	1989	
Mylvinskoye North *(Severnoye)*	Oil	1956		Veyakshor	Oil	1990	
Naul' (Naul'skoye)	Oil	1979		Visovoye	Oil	1989	
Nertsov	Oil			Vodnyy Promysel	Gas	1981	
Nertsov West *(Zapadnyy)*	Oil	1992		Voyskoye	Oil	1978	
Nibel	G & O	1945		Voyvozh (Voyvozhskoye)	O & G	1940	
Nizevoye	Oil	1986		Vozey	O & G	1971	
Nizevoye South *(Yuzhnoye)*	Oil	1989		Vozey East *(Vostochnyy)*	Oil	1988	
Nizhnyaya Chut'	Oil	1975		Vozey South *(Yuzhnyy)*	Oil		
Nizhnyaya-Omra	G & O	1951		Vozey West *(Zapadnyy)*	Oil		
Nyadeyyu	Oil	1984		Vozeyshor	Oil	1991	
Nyamed (Nyamedskoye)	Gas	1947		Vuktyl (Vuktyl'skoye)	GC & O	1964	
Onekatyn	Oil	1990		Yagtyda	O & G	1958	
Osh	Oil	1986		Yanemdey East *(Vostochnyy)*	Oil	1991	
Oshkoto	Oil	1990		Yarega (Yaregskoye)	Oil	1932	
Oshkoto North *(Severnyy)*	Oil	1992		Yareyyu	OG & C	1973	
Oshkotyn West *(Zapadnyy)*	Oil	1988		Yaromusyushor	Oil	1991	
Osovey	Oil	1990		Yartyaga	Oil	1990	
Pachga	Gas	1970		Yaryayyaga West *(Zapadnaya)*	Oil	1990	
Padimey	Oil	1977		Yugid	OG & C	1933	
Palyuskoye	Gas	1960		Yugid-Vuktyl	Gas		
Palyuskoye East *(Vostochnoye)*	G & C	1959		Yuriy Rossikhin	Oil	1993	
Pashnya (Pashninskoye)	OG & C	1963		Yurvozh	Oil	1983	
Pashshor	Oil	1977		Yuryakha South *(Yuzhnaya)*	Oil	1988	
Passedskoye	Oil	1990		Zelenets (Zelenetskoye)	Gas	1968	
Patrakovskoye	Gas	1970					

* Fields that might also contain Siluro-Ordovician sourced hydrocarbons (as per Abrams and others, in press).

\# Fields that are considered part of a Triassic-sourced petroleum system more related to the South Barents geologic province.

Table 2. Timan-Pechora Basin Province
Reserve Allocations and Reservoir Characteristics by Age and Lithology

	ALL RESERVOIRS				SANDSTONE RESERVOIRS						CARBONATE RESERVOIRS						
RESERVOIR AGE	Avg. Poro (%)	Avg. Perm (md) (arith / geom)	Avg. Net Thickness (m)	Allocated Reserves * mmboe *(% of all)*	Reserves * mmboe *(% of horizon)*	Avg. Poro (%)	*Max Poro (%)*	Avg. Perm (md)	*Max Perm (md)*	Strat Traps (%)	Reserves * mmboe *(% of horizon)*	Avg. Poro (%)	*Max Poro (%)*	Avg. Perm (md)	*Max Perm (md)*	Strat Traps (%)	HC TYPE
POST-HERCYNIAN																	
Triassic	22.5	75 / 39	7	1344 *(12)*	1344 *(100)*	22.5	*28*	75	*340*	(3)	0 *(0)*					(0)	variable
Upper Permian (pt 3)#	19.3	156 / 53	9	1103 *(10)*	1081 *(98)*	19.5	*27*	156	*1113*	(5)	22 *(2)*	9	*9*	120	*120*	(0)	variable
"UPPER PALEOZOIC"																	
Lower Permian (pts 1,2,3)#	15.3	134 / 70	19	3178 *(27)*	763 *(24)*	15.9	*24*	184	*765*	(4)	2415 *(76)*	15.1	*28*	118	*650*	(22)	variable
Upper Carboniferous (pts 1,2)#	13.2	120 / 68	19	1164 *(10)*	70 *(6)*	13.2	*19*	195	*840*	trace	1094 *(94)*	13.2	*19*	95	*250*	(5)	variable
Lower Carboniferous (pt 1)#	14.9	117 / 66	9	129 *(1)*	50 *(39)*	14.4	*20*	137	*350*	(0)	79 *(61)*	15.8	*20*	89	*257*	(0)	variable
Upper Devonian (pt 3)#	12.9	260 / 97	15	3019 *(26)*	1268 *(42)*	13	*20*	372	*4000*	(31)	1751 *(58)*	12.9	*25*	177	*1200*	(14)	variable
Middle Devonian (pts 2,3)#	13.7	239 / 72	13	& 708 *& (6)*	708 *(100)*	13.7	*25*	239	*3560*	(9)	0 *(0)*					(0)	variable
"LOWER PALEOZOIC"																	
Lower Devonian	10.8	162 / 84	22	680 *(6)*	61 *(9)*	13.7	*16*	52	*85*	(0)	619 *(91)*	10.4	*14*	179	*413*	(23)	all oil, 26-41 API
Upper Silurian	9	63 / 62	?	? *?*	0 *(0)*					(0)	? *(100)*	9	*10*	63	*80*	(100)	all oil, 32-35 API
Lower Silurian	10.5	93 / 81	10	148 *(1)*	1 *(1)*	12	*12*	15	*15*	(1)	147 *(99)*	10.4	*16*	99	*150*	(21)	mostly oil, 23-39 API
Silurian	10.8	387 / 177	17	58 *(Tr)*	14 *(24)*	11.5	*12*	115	*200*	(0)	44 *(76)*	10.3	*11*	930	*930*	(0)	all oil,15-40 API
Upper Ordovician	11	3	31	78 *(1)*	0 *(0)*					(0)	78 *(100)*	11	*11*			(0)	oil and gas
ALLOCATABLE TOTALS	14 avg.			10901 *(100)*	5360 *(46)*	16 avg.		154 avg.		avg. 4.4	6249 *(54)*	13 avg.		208 avg.		avg. 15.4	

* Reserve numbers are ultimate recoverable (all data derived from Petroconsultants, 1996).

Timan-Pechora known recoverable reserves total 19978 mmboe, but just 58% (11609 mmboe) can be allocated to reservoir horizons with available porosity, net thickness and oil saturation information. The three largest producing fields listed below contain 30% (5908 mmboe) of all Timan-Pechora known recoverable reserves. They are distributed within the above-noted reservoir horizons in unknown proportions.

1 Vuktyl
2 Usa
3 Vozey

& Middle Devonian siliciclastic volumes under-represented (Umishek, personal communication, 1998), possibly because of inclusion with Upper Devonian category.